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Engineering
News-Record

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HIGHWAY MAINTENANCE

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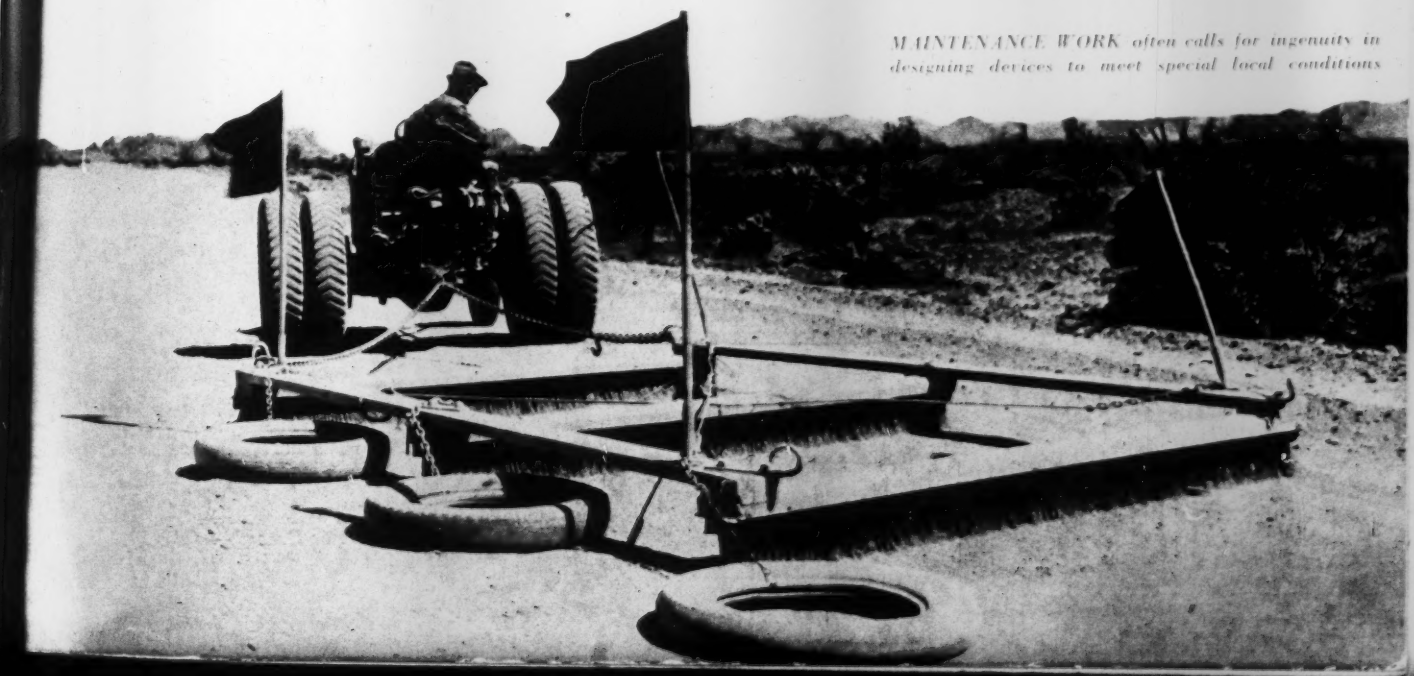
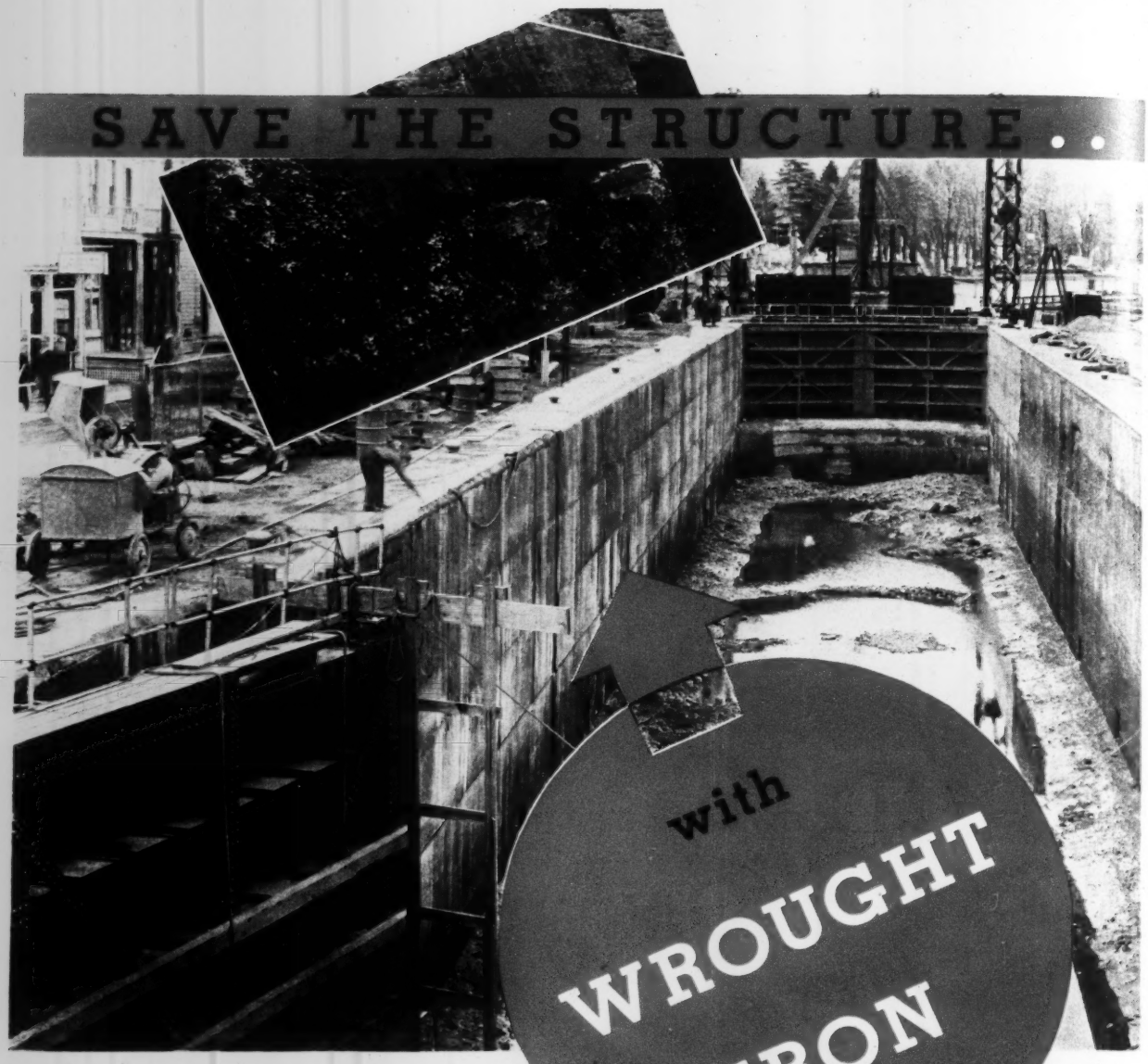
MAINTENANCE OF HIGHWAYS is a task of ever increasing importance but one about which little has been written. . . . This issue is devoted to a discussion of the maintenance man's tasks. Organization and direction, management of equipment and maintenance process are reviewed by men in authority in the highway world.



MAINTENANCE WORK often calls for ingenuity in designing devices to meet special local conditions

SAVE THE STRUCTURE . . .



Sea, harbor, river and canal water exact a heavy toll from structures not protected against corrosion and the spalling caused by freezing and thawing. That's why engineers responsible for piers, locks and bridge piling use wrought iron plates *to save the structure.*

Illustrated is a recent example. The walls of Lock No. 24, Baldwinsville, a part of the New York State Canals System, were seriously affected by spalling. Byers Wrought Iron Plates were used for resurfacing. They were cinch anchored (also wrought iron) into place and back filled with grouting. Now the lock walls are protected in the high-low water range even against bumping. More details regarding this and similar installations will be found under Pier Protection in the new edition of "The Use of Wrought Iron in Bridge Construction," just published.

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A MOMENT WITH THE PUBLISHERS

The Railroads *Go to Town*

THIS is written on the eve of "Railroad Week," set apart to broadcast the accomplishments of the railroads. There is to be, of course, the regimented blowing of locomotive whistles, the crowning of a "Queen" and other frothy ballyhoo; but, happily, there are to be more substantial demonstrations of the noteworthy progress the railroads are making.

In a way, "Railroad Week" signalizes a rejuvenation. For some years past the railroads have been on the defensive and feeling a bit sorry for themselves. Naturally enough, in their public relations, they have resorted frequently to the dubious defensive tactics of the underdog. But today they are putting all that behind them—at least, many of them are.

They are taking the offensive and are invoking the one convincing answer to criticism. They are "showing 'em" rather than just "telling 'em"; they are demonstrating that the railroads still can forge ahead to higher standards, which is far more effective than merely trying to maintain parity by holding back newer instruments of transportation to obsolete standards. Already, by their new tactics, some railroads are reclaiming traffic that they had been consistently losing. Others will follow suit. All this makes for real progress and it is altogether fitting that the American people should be made to recognize the new spirit that animates their railroads.

THE other day Ralph Budd, president of the Burlington, and an aggressive disciple of the new tactics, revealed to a conference on unemployment a wee glimpse of the promise offered by this rejuvenation not only to those who use the railroads directly, but also to the nation-at-large.

During the depression, he tells us, 20 per cent of the railroad freight equipment has worn out and another 20 per cent has become obsolete. The roads will require 100,000 new freight cars each year during the next fifteen or twenty years and must spend $250,000,000 annually for them. Twenty new and ten rebuilt streamlined passenger trains are to be put into operation this year, he says, with a consistent development of new types and improvements.

But it is not only in such spectacular developments that the rail carriers are displaying new spirit and enterprise: new standards prevail in the handling of freight as well as passengers; new standards of safety for the rail traveler; new standards of service for coach as well as Pullman passengers; a speeding up of schedules that seems all but miraculous in its scrapping of generally accepted norms.

All of which demonstrates incidentally that competition still is useful, even to those who may deem it a menace to be suppressed by hook or crook. No one can say for how long the germs of these improvements in railroad service have been breeding, but it is reasonably certain that their incubation has been materially hastened by the heat of competition.

Some men will work against a self-imposed bogie just as hard as they will against a more personal and independent competitor, but they are in the minority. Especially in the domain of finance, which has wielded so heavy an influence in railroad affairs, it is not easy to sell progress for its productive values; the lack of progress usually must be converted by outside competition into downright loss before the driving incentives required for progress can be generated.

BUT whatever may be the stimulus, the dominant fact is that some railroads today are going to town. In morale, technique and driving power they are rising to their responsibilities and opportunities. In their willingness to question the orthodox and try the new, in their emphasis on their accomplishments rather than their grievances, in the vision that bids them fight for their share of tomorrow rather than bemoan or avenge their losses of yesterday, they are setting a pace worthy of their finest traditions—and those are plenty fine.

Engineers and other technicians who find in the progressive management of industry the chief demand for their experience and skill will hail the rejuvenation of a field in which they have recorded some of their most notable achievements.

Willard Chevalier

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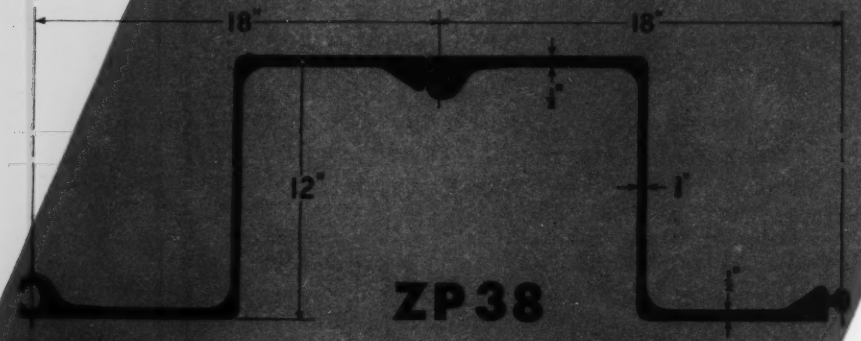

Weight per linear foot of pile	57 lbs.
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■

New American Records—Olympic Year suggests records. Out in Nebraska a 109-ft. span concrete, rigid frame bridge sets a new American record. It is part of a 56-bridge program just completed by the Loup River Public Power District and will be described in next week's issue.

WARNING ALL CARS— KEEP TO THE RIGHT!

Traffic markers of Atlas White Portland Cement on West Jefferson Avenue, River Rouge, Michigan
Installed by Board of County Road Commissioners, Wayne County, Michigan. J. K. Norton, Road Engineer

UNTIL two years ago, traffic on this street *crawled*. Now cars move swiftly, orderly, *safely*. The change came when, in 1934, the pavement was widened to 90 feet, and a marker of Atlas White Cement was installed straight down the middle.

In town, or in the country, the fellow behind the wheel has a wholesome respect for these white markers. (Many drivers would no more think of crossing the line than of crossing a hard-boiled cop.)

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ENGINEERING NEWS-RECORD

July 30, 1936

HIGHWAY MAINTENANCE NUMBER

Keeping the Main Road Open

ABOUT A THIRD of a billion dollars annually is spent to keep the highways of the United States in repair. Every new year adds to this cost as roads grow older and traffic calls for better maintenance service. By whom is the money provided; who controls its expenditure, and how are the controlling agencies organized to apply the funds and to perform the repair operations? These questions find answer in this issue in statements by leading highway officials dealing with department organization, equipment management and maintenance methods.

To maintain the road conditions demanded by modern highway transport, department organization has to be permanent. From routine road patrol to patch up ravelled spots of traveled surface, maintenance operations extend to major offensives in which whole divisions of men and equipment are flung back and forth across states to repel the attack of blizzard snowfalls and repair the damages of flood and frost. A practiced directing and working force is required to cope with this range of operations, and sound organization and permanence of personnel are questions of the most vital consideration.

The weapons of the maintenance army are machines and craftsmanship. Of the 200,000 maintenance workers on American roads the great majority are trained operators and skilled workers in concrete and bitumen, in bricklaying and soil-stabilization. Maintenance methods as practiced go beyond patching to skillful restoration and improvement of original structure; they call for tools and machines now represented by state plant inventories ranging from one to four million dollars. The selection, repair, operation and financing of these great plants is second only to department organization in insuring continuous road upkeep.

CURRENT UPKEEP represents the squad actions of maintenance; when flood and frost and snow swing into attack army movement is demanded. Detailing of troops then changes to mobilizing whole divisions and moving them swiftly into offensive against the elements. In snow control and removal is represented this combined action of department organization, equipment management and working methods. All must come into action if transport is to be served by the open road in winter.

The problem of maintenance needs understanding by highway users so that it can be better solved. Money support is inadequate because of diversion of funds that has restricted maintenance equally with construction. Notable organizing and engineering talent has been applied to road upkeep; money support will capitalize it as direct service to transport. This issue is directed to that end.

Road Upkeep—The Problem

Highway maintenance is a $350,000,000-a-year government business on the careful management of which road transport depends for economic life

By Charles Dwight Curtiss

Chief, Division of Control
Bureau of Public Roads,
Washington, D. C.

HIGHWAY maintenance has become one of the most skilled engineering operations and one of the largest of government businesses. Transport by road owes its ease and safety of travel to maintenance as much as to design and construction and maintenance provides the open road in winter when snow and ice invest the land. So that the roads may be maintained, national, state and local governments have set up a partnership of standards, control, finacing and engineering practices that ranks among the greatest and most comprehensive activities that serve transportation.

This article discusses the manner in which the national government plays its part in the maintenance of public roads, considering more specifically definition, volume and expansion; federal supervision; improvements required in accounting, and new economic problems forecast by maintenance experience.

Some cold figures

The best available records indicate that there are in excess of 3,000,000 miles of rural roads in the United States. These roads vary from the two-, four- and six-lane highways and parkways in densely populated areas, carrying very heavy traffic, to the scarcely-used roads in sparsely-settled country that are little more than trails. In some states the poorest local roads are mere section-line rights-of-way; they are legal highways, but may seldom if ever be traveled.

By the end of 1934 a total of 324,312 miles had been included in the main state highway systems, and in 14 states an additional 170,244 miles of secondary roads had been brought under the jurisdiction of state highway departments. Of the rural mileage under state control, 271,600 miles of primary and 74,450 miles of secondary roads had been surfaced by the end of 1934.

The remaining 2,500,000 miles of secondary and land-service road are under the jurisdiction of the counties and smaller local units. Of this mileage it is estimated that about 630,000 miles had been improved with some type of surfacing by the end of 1934.

A great public business

Definition comes first. In carrying forward programs of highway improvement a practice of building up to the final type through successive improvements has been developed; this is frequently referred to as stage-construction. Sometimes certain of the stages of construction are handled by maintenance forces under the classification of betterments, and sometimes these betterments through so-called "heavy maintenance" merge into construction or reconstruction. An example would be scarifying; widening with the addition of new material, and surface-treating an old gravel or macadam road.

It should be clearly understood that such work may not properly be classified as maintenance even though handled by maintenance organizations. Any betterment that raises the type of construction or any addition that increases or improves the carrying capacity of a highway should be classified as construction and not maintenance; the cost of such work is capital outlay, not maintenance cost.

But the originally narrow definition of true maintenance has itself grown broader in recent years. By statute, highway maintenance has been defined as "the constant making of needed repairs to preserve a smooth-surfaced highway." When restricted to the roadbed or width between the outside shoulder lines, this definition is satisfactory. Through the years, however, state highway departments have changed from being merely roadbuilding agencies and are now engaged in the tremendously-enlarged and important task of operating and administering highway systems. Accompanying this evolution, there has been a material growth in the activities of maintenance organizations. Their work has been extended to cover the full right of way, including surfacing, shoulders, ditches and backslopes, structures, roadsides, footpaths, informational and directional signs and markers; and, in winter, snow removal and treatment of icy pavements. A more complete definition may be suggested as follows:

General highway maintenance is the preserving and keeping, through constant attention, of each roadway and roadside structure and facility as nearly as possible in its original condition as constructed, or as subsequently improved, to provide satisfactory and safe highway service.

This definition of general maintenance does not include reconstruction or additions and betterments, but it does include far more extended services to transport; among these snow control is a striking example. Within a few years the removal of snow, and ice treatment, have made posible practically uninterrupted travel on our main highways through the winter months. During the winter of 1934-35, according to reports received by the U. S. Bureau of Public Roads, snow was cleared from 186,000 miles of main highway in 36 states. To assist in controlling snow drifts, 10,231 miles of snow fence were used. The total expenditures reported for this type of work amounted to $11,821,000. The additional highway revenue in gasoline taxes resulting from the uninterrupted travel made possible by keeping the roads open in the winter months probably more than pays for the snow removal work.

As maintenance is now conducted, the expenditures of the state highway departments for maintenance work in the past two years have been about $180,000,000 annually. Entirely reliable figures of expenditure for the maintenance of local roads by all the numerous units of government handling such work, are not available, but it is estimated that over the same period these expenditures have averaged about the

same as those for state highways. Thus the annual expenditure for maintaining rural highways exceeds $350,000,000. This expenditure provides employment for large numbers of workers; the available statistics show that state-highway-department maintenance operations gave employment to an average of 151,000 each month during 1933, 156,000 during 1934, and 136,000 during 1935. Observe that these figures do not include country or township maintenace workers.

Maintenance funds for state highway systems are allocated from the collections of the state gasoline taxes or motor vehicle license fees, and the road user quite properly pays the full bill. To a lesser extent the maintenance costs on secondary roads are met from road-user tax funds collected by the states and transferred to the counties. These funds are supplemented where necessary by special road levies or appropriations from the general funds. Maintenance costs of the roads which serve principally the lands bordering on them, as well as of the less important secondary roads, are met largely from property taxes.

While a few maintenance operations, such as the application of bituminous materials for surface treatments, may be handled satisfactorily by contract, the general nature of the work is such that it can best be done by force account under competent engineering supervision. Under this method of maintenance management, the necessity of competent engineering supervision of operations cannot be too strongly emphasized; a high order of engineering skill is required to meet the exacting problems involved in keeping both the heavily-traveled routes and the secondary roads in condition.

Supervision on federal-aid roads

Under the basic federal legislation, which provides for the co-operation of the federal government with the state highway departments, federal funds apportioned to the states are available only for construction, not for maintenance. The importance of highway maintenance was however recognized by Congress when it passed the Federal Highway Act of Nov. 9, 1921, and it included a strict requirement for the maintenance of roads constructed with federal aid. This is covered by Section 14 of the act, which reads in part as follows:

Should any state fail to maintain any highway within its boundaries after construction or reconstruction under the provisions of this act, the Secretary of Agriculture shall then serve notice upon the state highway department of that fact, and if within ninety days after receipt of such notice said highway has not been placed in proper condition of maintenance the Secretary of Agriculture shall proceed immediately to have such highway placed in a proper condition of maintenance and charge the cost thereof against the federal funds allocated to such state, and shall

TRAFFIC LANE MARKING and brightly painted bridge steel characterize modern maintenance, as represented by a Virginia road crossing Middle River near Staunton.

SHOULDERS, ditches and backslopes require as much maintenance consideration as the pavement itself. In a Missouri road, above, note the lip curb and drain to the side ditch.

MAINTENANCE today looks carefully to neatness around roadside service structures, as represented by this market on a typical three-lane Massachusetts highway.

refuse to approve any other project in such state, except as hereinafter provided.

Upon the reimbursement by the state of the amount expended by the federal government for such maintenance, said amount shall be paid into the federal highway fund for reapportionment among all the states for the construction of roads under this act, and the Secretary of Agriculture shall then approve further projects submitted by the state as in this act provided.

Although in a few instances it has been necessary to call the attention of a state highway department to an unsatisfactory maintenance condition, it has not been necessary for the Secretary of Agriculture to take over the maintenance of any project and charge the cost of such maintenance to the state as provided in the section of the act quoted.

The condition of projects constructed with federal aid and the quality of maintenance are determined by regular inspections made by engineers assigned to this work in the district organizations of the Bureau of Public Roads. The bureau requires at least two inspections of each project each year, one of which must be in the first half and one in the last half of the calendar year. A special system of rating the quality of maintenance has been developed; one form is used for highways and small bridges, and a separate one for large bridges, in which the several elements are rated on a basis of 100 as perfect.

The forms are designed so that the inspection report will show not only the quality of maintenance but the condition of the project at the time the inspection was made. A rating below 60 is considered unsatisfactory. Also a very low rating in one of the elements may be sufficient to class the project as temporarily unsatisfactory. If the condition of a project because of unanticipated increase in traffic is such that the improvement is not providing satisfactory service in spite of proper maintenance efforts, a recommendation for reconstruction to a higher type is made.

Coming problems

One of the serious maintenance problems is the lack of uniformity in the systems of accounting for maintenace costs in use in the several states. Some of the principal defects in various maintenance records are as follows: (1) Costs are not segregated by types of construction and age; (2) Costs are not distributed among the several elements of the highway, such as surface, shoulders, drainage, structures, roadside and traffic service; (3) Costs of betterments, reconstruction and additions are sometimes classified as maintenance if handled by maintenance organizations, and (4) Many items are prorated by arbitrary percentages instead of being distributed by actual costs.

If a dependable breakdown of maintenance costs by roadway elements and surface types is not available, the preparation of a maintenance budget on a scientific basis is difficult if not impossible. Reliable maintenance-cost data are of great value in planning programs of construction and reconstruction and are necessary if the proper balance between construction and maintenance costs is to be secured with maximum service to the public.

At the present time the Bureau of Public Roads is cooperating with the several state highway departments in a special study of maintenance costs on selected sections of highway, on which complete data are being accumulated. This special study includes 17,762 miles of highways, made up of 1,092 different sections and eight different types of construction. A special form has been developed, on which the cost data and other pertinent information are accumulated by years. A still more detailed cooperative study is being carried on by the Bureau of Public Roads and the state highway departments of Connecticut, Rhode Island and New Hampshire, in which the carefully accumulated maintenace costs will be correlated with traffic studies made currently on the selected sections.

It is hoped that through these special cooperative studies of selected sections and types of highways a convincing accumulation of reliable maintenance cost data will impress highway officials with the importance of adequate and uniform maintenance-cost accounting. Committee work of the American Association of State Highway Officials and other regional groups is helping toward solution of this problem.

Adoption of a uniform system of maintenance cost accounting by all the state highway departments would make possible a comparison of the costs of maintenance of various types of construction under different climatic and service conditions. The experience of other states could be drawn on in this field much more extensively than is possible under present conditions. The matter has an important place in the economics of highway transportation.

The severity of the past winter taxed the resources of highway maintenance organizations. Operations involving snow removal and treatment of icy pavements were hardly over before the frost began to leave the ground. Prolonged low temperatures in many sections had frozen the ground to an unusual depth, and with the advent of mild weather unstable subgrades softened. Because of the loss of support the surfacing, particularly thin surfacing of the so-called low-cost type, suffered considerably. Traffic restrictions were resorted to, but there was much deterioration of a considerable mileage and the maintenance organizations were confronted with a formidable task. In restricted areas floods resulting from melting snow and heavy rainfall produced additional damage.

These lessons of the past winter emphasize particularly the importance of subgrade stabilization, and will undoubtedly result in greater utilization of established principles of subgrade treatment in the construction of highways and give impetus to further study of this very important subject. A question of public policy is also raised by these failures. The failure of low-type roads built on too low a standard in an attempt by public officials to meet the insistent demand for increased mileages of motor roads emphasizes the fact that such construction may be low in first cost only and not really economical. The increased maintenance costs of improvements inadequate to withstand both traffic and natural forces may more than offset the saving in first cost.

The creation of a burdensome maintenance obligation for future years through construction of substandard low-cost roads should be avoided, so that a continuous construction program may be carried forward. This criticism applies only to unduly cheap construction, which creates a difficult problem in the financing of future maintenance and construction, and not to the rational extension of adequate low-cost secondary improvements that can be economically maintained.

Tax diversion serious

Another problem, which is not directly one of highway maintenace but which may have a disastrous effect upon maintenance work, is the growing tendency in the states to divert the proceeds of the gasoline tax and of motor-vehicle license fees to other than highway purposes. These diversions have been increasing for a number of years, and reached a total of about $142,000,000 in 1934, which was about 25 per cent of the amount allocated to the state highway departments in the same year from these taxes for construction, maintenance, debt service and miscellaneous expenditures.

Accompanying this decrease in income to the state highway departments has been the added responsibility for an increased mileage of primary and secondary highways brought under their jurisdiction. The transfer of additional highways to the jurisdiction of a state highway department brings with it the public expectation of improved standards of maintenance and the hope of much new construction. This trend in the direction of larger state highway systems and the extension of the state highway department's jurisdiction to the more important secondary roads will doubtless continue. Even with their greater efficiency and superi[illegible] organizations the efforts of the state highway departments will necessarily be limited by the available funds, and the continued diversion even at the present rate constitutes a real danger to highway maintenance operations.

Machine Work Prevails

Variety of equipment and many special-purpose machines, usually representing a plant investment of several millions, call for able technical and business organizations in each state

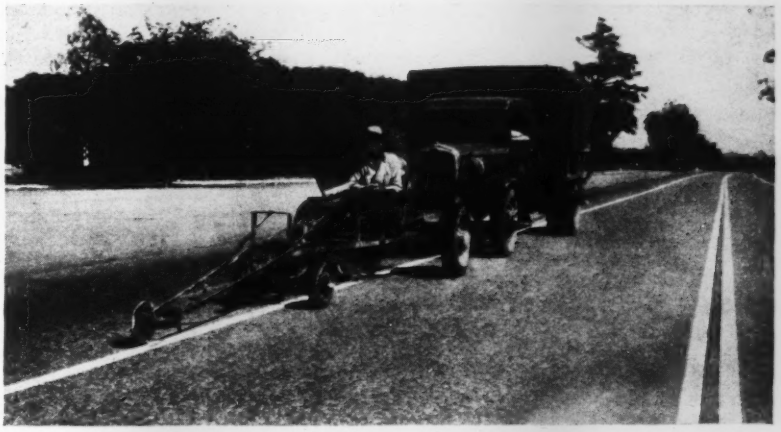
By T. H. Dennis

State Highway Maintenance Engineer, California Division of Highways, Sacramento, Calif.

HIGHWAY maintenance departments are the largest owners and operators of road machinery. They have therefore of necessity had to develop comprehensive systems for selecting, financing, distributing, servicing and repairing this machinery and precise methods of keeping accounts of these activities.

Most maintenance equipment is highly specialized, and is the product of invention and experience within maintenance organizations. The most striking example of this development is the improvement of the one-man tractor-grader to its present usefulness. It began with the simple attachment of a road drag beneath a light tractor. Later, graders similar in type to ordinary pull-graders were developed, utilizing the front truck of the tractor to support the front end of the grader. Since the small tractor lacked sufficient power to handle an 8-ft. blade to its best advantage, a new machine was designed around a 10-20 industrial tractor, and a commercial road machinery plant was commissioned to build it. This one-man tractor-grader was a pronounced success, and this machine with continuing improvement in design has since been commercially available.

Similar pioneering work has contributed largely to the improvement in the present pull-graders. For example, the standard practice in building road graders was to provide only the crudest method of pin and hole for take-up in the control arms, with the result that the constant chatter soon rendered these almost useless. Take-ups designed so that accurate adjustments were possible were then developed, and manufacturers have since made such adjustment standard on their machines.



TRAFFIC striping done with a machine pushed by a truck which carries paint tank and pump gives the operator a long sight distance; either single or double stripes can be painted.

The severe damage which resulted when graders equipped with plain steel-tired wheels with simple hub and axle were towed at reasonable speeds led to the development of rubber-tired wheels and high-speed bearings. Further improvements were made on these units with the installation of large-size pneumatic tires.

The detachable trailer boot for oil distribution, which was the result of a suggestion by one of our maintenance engineers, is also worthy of mention. It makes an independent unit of the distributor boot, which ordinarily is a permanent part of the truck tank distributor. It is readily attached and detached in the field and eliminates the delay attending the pumping from tender to distributor tank. Since its development at least three commercial firms have engaged in its manufacture.

Our large snow removal program has also stimulated the development of equipment required in this work. Notable examples are the wing plows mounted on trucks for widening snow cuts; and the slice bar attachment, also mounted on trucks, which is used to reach and cut down the high overhanging banks of snow left after the passing of ordinary snow-removal equipment. Snow removal operations on a large scale and of the most difficult and rough kind have taxed to the utmost the ability of both operators and equipment with the result that many minor improvements of commercial machines have been made and practically every piece of snow-removal equipment in use has been strengthened and reinforced in the attempt to prevent breakdowns at critical times.

Other accomplishments of cooperation are emulsified asphalt rigs, portable horizontal retorts for the heating of oil in the field, improvements in traffic striping machines, transmission for driving road sweepers, and many lesser ones.

California's experience in the development of maintenance equipment is typical of that performed by other maintenance and equipment organizations. In the discussion that follows, all these phases of equipment management are considered first as to selection and use, and second as to management.

MACHINE WORK PREVAILS . . .

I—Factors Governing Selection

THE SELECTION of maintenance equipment depends on the type of road surface, and on the general, special and seasonal character of the work. Usually, less equipment is required per mile for the general routine maintenance of the higher type pavements, such as asphaltic and portland-cement concrete, than for either the intermediate types of oil macadams and mixes or the lower types of untreated natural or metalled surfaces. Equipment for special work such as grading, slide removal, drainage, oiling and snow removal, will of course depend upon the magnitude of the work. The economy of owning such special equipment must be considered in the light of the yearly recurrence of these operations and the availability of equipment from private sources when needed.

Surfacing equipment

Selection of equipment for maintaining surfaces varies with the type of surface, although many items are common to all types. For this reason it will help selection to consider the chief surface types separately. There are three that need to be considered.

High-Type-Surface Equipment — Equipment for the higher-type surfaces usually includes 1-yd. or 1½-yd. power-dump trucks supplemented with either emulsified or hot-asphalt kettles of 110- to 300-gal. capacity. Where the patching is extensive and of considerable depth, three-wheel 6-ton gas rollers are desirable. If the patching is shallow, a 500-lb. hand roller may be used. Both kettles and hand rollers should be equipped with pneumatic tires for mobility. Rubber-tired trailers should also be provided for the larger-size rollers.

A considerable range in the size of asphalt kettles may be permitted, depending upon the method of asphalt delivery as well as the type of asphalt. When asphalt can be furnished daily from a plant, and retorted to desired temperatures, the 200- to 300-gal. kettle, mounted on a four-wheel, rubber-tired trailer and equipped with warming oven and pressure-operated pump and spray bar, is desirable. Where the asphalt is furnished in 110-gal. drums, the kettle should have a heating compartment capable of holding one drum, with a lower warming oven for carrying an additional drum which can be warmed and the asphalt pumped into the upper compartment as needed.

If emulsified asphalt is used, the size of kettle will depend upon the size of the crew; a 165-gal. two-wheel outfit is sufficient for a three-man crew, and a 300-gal. four-wheel unit for larger forces. Both units should be equipped with an engine-powered pump and air compressor. Where premix oil material is available for patching, a 75-gal. kettle with power-operated pump and spray bar is adequate for both tack coating and crack filling.

The grading of natural soil shoulders adjacent to these high type pavements is usually performed with tractor graders, one unit being capable of blading from 10 to 15 miles per 8-hr. day. There are on the market today several different types of tractor graders, chief among which are the single drive and the dual or tandem drive. The single drive is suitable for light shoulder blading where traction is good. For heavier work the tandem drive will be found the better unit, due to its greater tractive power. Under adverse conditions of traction and gradient, the tandem drive with dual tires is preferable. Tractor graders are rapidly supplanting pull-type graders, except on heavy grading, ditch work and certain types of oil mixing. This is due to their greater mobility and lessened operating costs through elimination of the extra operator required on the pull-type grader, towed by tractor or truck.

Intermediate-Type-Surface Equipment —Intermediate-type pavement maintenance normally requires scarifying or disking units, and often pavement burners, in addition to the equipment listed as necessary for the high-type surfaces.

Scarifying units are selected to meet particular conditions. Special units have been constructed with chisel-shaped teeth set in a heavy rigid frame supported on a long-base, heavy, four-wheel, rubber-tired trailer which is pulled by a 75 hp. tractor. This, of course, is for smoothing roughened oil macadams and is usually rented from private sources. The same general arrangement with a battery of burners placed immediately in front of the chisel teeth has lately appeared and is having some success.

On the lighter oil surfaces, successful work has been performed with a heavy disk scarifier pulled by either a truck or a tractor. Four sets of 12 or 13 disks each are mounted on a long-wheel-base pneumatic-tired trailer. This gives a 2-in. spacing, and where wider spacing is desired it can be accomplished by removing every other disk. Recently, disk attachments for either tractor or pull-graders have been placed on the market, and have proved quite successful.

Pavement burners are now available in various forms, from the single-hand torch and batteries of burners operating under a steel hood to more pretentious units capable of rapidly treating large areas of pavement. The smaller units prove handy in drying limited surface areas under adverse weather or temperature conditions, prior to applying tack coats for premix or oil-macadam patches. The larger units are used to heat more extensive surface areas which have distorted under traffic. The heated material is raked off immediately following the removal of the burner.

Low-Type-Surface Equipment — The maintenance equipment required for low-type untreated surfaces, either natural or metaled, may include graders, pull or tractor type; drags or road maintainers; tooth scarifiers; trucks; crawler or wheel-type tractors and water tanks.

Mention has been made of the tractor-type motor grader, and where this unit must furnish the general tractive power, it should preferably be of the tandem drive wheel type, powered with an engine developing 40 hp. Scarifier attachments are available for these motor graders, and the unit mentioned has adequate power to do scarifying. If heavy ditch grading or bank sloping is necessary, a crawler-type tractor of equivalent power is desirable. This unit, coupled with an 8-ft. rubber-tired leaning-wheel high-lift grader will meet general demands. There will be a certain sacrifice of mobility in this assembly, which can be overcome by substituting a 4- to 5-ton, four-wheel drive truck for the crawler-type tractor. Such a combination is usually adopted if slide or snow removal is part of the routine work. The combinations of heavy-truck or crawler-type tractor should however be supplemented with either a dual-drive motor grader or pneumatic dual-tired tractor and multiple-blade maintainer. Either of the above units will satisfactorily maintain 20 to 30 miles of road surface; the crawler-type tractor with pull grader would be pressed to maintain half this distance.

The transportation of laborers assigned to surface work may be provided by 1½ or 2-ton trucks.

Where the road surface is sprinkled, it is customary to use a 1,000-gal. tank mounted on a suitable two-wheel-drive truck equipped with an engine-driven pump for filling. The tank should be

interchangeable with the ordinary truck body to insure full use of the equipment at the end of the sprinkling season.

Grading equipment

Grading on maintenace is usually limited to minor line changes, drainage corrections or slide-removal. The equipment used includes gas or diesel-powered shovels, draglines, trucks, tractors, bulldozers, revolving scrapers, stone boats, compressors and drills.

Power Shovels — There is a wide range of choice as to size, type of power and traction in power shovels but mobility and tractive conditions normally govern the selection. The three smaller sizes generally available are ⅜-, ½- and ¾-cu.yd. Either of the first two shovels under average conditions will handle about 275 cu.yd. of material per eight-hour day, and the ¾-cu.yd. model about 375 cu.yd.

On account of their small size, the ⅜- and ½-cu.yd. shovels are practically limited to loose earth and gravel, and since the cost of their operation is only slightly less than that of the ¾-cu.yd., the latter size is generally preferable.

While the diesel-powered shovel appears steadier and is more economical of operation, many of our runners are not yet familiar with the diesel engine, nor is fuel always available in remote sections. These conditions will no doubt shortly adjust and correct themselves.

In general, the truck-mounted shovel has a distinct advantage in moving to, from and along the work. The present limiting size is the ½-cu.yd. It has two disadvantages; one is the lack of traction under soft or muddy conditions usually encountered in slide-removal work, which prevents it from being kept up close to the material; the other is the necessity for the operator to leave his controls to move the machine. These disadvantages do not obtain in the crawler-type mounted shovels, and with the present practice of moving them on rubber-tired trailers their general mobility is not impaired.

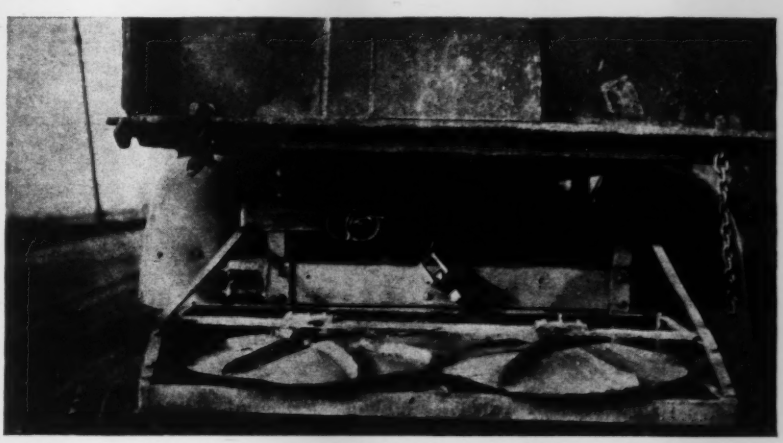
Trucks and Tractors—Where trucks must supply the tractive power for pull graders, the 3-ton to 5-ton four-wheel-drive type is desirable. If used for transporting material alone, the conventional two-wheel-drive unit is satisfactory. The performance of these trucks will depend upon the length of the haul and the method of loading. The large 3-ton to 5-ton trucks should be used under shovel loading where the hauls are long; the 2-ton to 2½-ton trucks should be used only under light shovels.

The use of wheel and crawler-type tractors depends upon the tractive conditions. Where satisfactory conditions obtain, the 8,000-lb. to 10,000-lb. wheel-type tractor can be used for pulling a 6,000-lb. 8-ft. grader. Where traction is difficult, the crawler-type tractor is necessary. These vary from 9,000 to 18,000 lb. in weight, and from 40 b.h.p. for the lighter units to 50 b.h.p. for the heavier units. The heavier size is generally used to pull an 11,000-lb., 12-ft. grader. Where diesel fuel is available, the diesel-powered unit is preferable due to its sustained power and marked economy in fuel.

Compressors—Two sizes of portable compressors are usually considered for maintenance or medium-heavy grading work, one with a guaranteed output of 105 cu.ft. of air per minute at 100 lb. pressure at sea level and the other a 210-cu.ft. machine. The former will operate one hammer, the latter two

PAVEMENT raising calls for a two-unit plant consisting of compressor and drills and a mud mixing and pumping unit.

ONE-DRUM asphalt-emulsion spraying machine hauled as a trailer to a truck; an extra drum of emulsion can be carried in a sling.



SPREADER on truck saves time in sanding slippery pavements; the disks spread the sand in a thin even layer.

hammers at elevations up to 11,000 ft.; at low elevations, two small hammers may also be operated by the 105-cu.ft. unit.

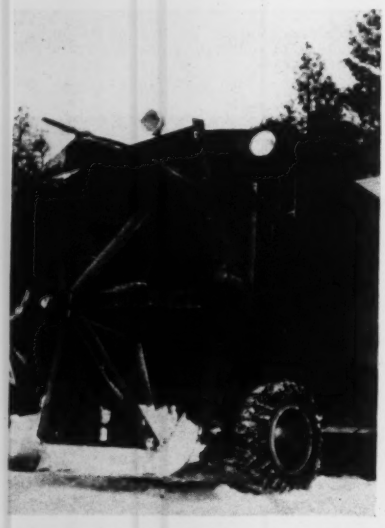
These compressors can be mounted on skids, trailers, trucks or crawler-type tractors. The skid or crawler-type mounting is used where the ground is rough and it would be difficult to move a truck-mounted unit; the skid type, however, will require more piping and hose, separate tractive power for moving and transportation for its fueling and servicing. The truck-mounted unit is easily shifted to permit shooting, and can be moved back and forth daily from storage for servicing, thereby offering less opportunity for vandalism and theft.

As a rule, the truck-mounted unit of 105 cu.ft. capacity is selected for routine maintenance where the work is light or scattered; on heavier work, the 210 cu. ft. size is more economical.

Drills—Jackhammer equipment may be limited to three sizes: light, about 40 lb., suitable for holes up to 6 ft. in depth; medium, about 48 lb. for a maximum depth of 12 ft., and heavy, 55 to 60 lb., for holes up to 20 ft. in depth. Hollow $\frac{7}{8}$ in. hexagonal steel is customarily used with these hammers.

The availability of detachable bits has revolutionized the former methods of sharpening drill steel and materially reduced its cost. These bits may be secured in either the flat chisel shape, or the four point cross-bit type, which can be sharpened on jack bit grinders equipped with suitable types of wheels. The cross-bit type requires the use of bit guides and gauges for satisfactory sharpening.

Draglines—The usual dragline equipment has but a limited use on maintenance, its principal field being on either drainage work or road material production. Even on drainage, the work can normally be performed with a power shovel, and if not, a dragline boom and bucket attachment may be purchased for installation on the standard $\frac{1}{2}$-cu.yd. power shovel, making it interchangeable with the shovel boom and bucket. On gravel production, a combination of either power shovel and trucks or crawler type tractors and scrapers will normally suffice.



DEEP SNOW BLOCKED mountain pass roads require the strength and capacity of railroad-type rotary snow plows.

Bulldozers—Bulldozers are becoming increasingly important on both grading and slide removal work, due to their speed and ease of operation on restricted road widths, regardless of tractive conditions. They are used extensively for spreading truck-dumped material, building pioneer roads and removing soft, mucky slide material. The unit should be mounted on not less than a 12,000 or 13,000-lb., 40-hp., crawler-type tractor.

Stoneboats—A new design in stone boats has been developed for attachment to a 9,000- to 10,000-lb. crawler-type tractor. It consists of a heavy steel plate attached to the drawbar of the tractor with two rigid steel channels. The boat is loaded, hauled to the edge of the embankment and backed over, eliminating hand unloading.

Scrapers—Revolving scrapers have a definite field in maintenance. A special type has been developed for operation over sandy soils. This unit of about $1\frac{1}{2}$ cu.yd. capacity is full revolving, and the loaded bowl is supported by two auxiliary solid wheels working on stub axles mounted on the side frame to the rear of the bowl. Scrapers of this size are pulled with a 35-hp. crawler-type tractor. Scrapers with wheel mountings should preferably have them mounted either to the rear of or within the bowl so that the scraper can be operated close to the cut banks.

Seasonal equipment

Road maintenance has distinctly seasonal tasks. Two of these of general scope are summer oiling and winter snow removal. Both tasks require special equipment that is laid up a part of the year.

Oiling Equipment—Oiling equipment includes truck distributors, trailer-distributor boot attachments, tank trucks, gang disks, pull graders, crawler-type tractors, motor graders and rollers.

The truck distributor is usually of 1,000-gal. capacity, mounted on a six-wheel truck. It has a spray bar, auxiliary engine and pump for circulating and spraying the oil, and is equipped with a tachometer, which is found to be more accurate at slow speeds than the ordinary speedometer in gauging the oil application. The trailer distributor boot is mounted on a two-wheel pneumatic-tired trailer, and consists of a spray bar, gasoline engine and pump, and is provided with tractive and oil connections for attachment to the ordinary tank truck. The truck distributor is more efficient on exacting work, on projects involving short hauls, and where hot asphalt or emulsified asphalt is being used. The distributor boot is superior in the distribution of light oils and saves the time of transferring the supply tanker's load, which is necessary with the truck distributor.

Mention has already been made of the various types of tractor and pull graders, crawler and wheel-type tractors, as well as rollers. The combination of pull-type grader with crawler-type tractor, however, has proved superior for oil mixing operations. The size of grader may range from 8 to 12 ft., with a tractive power range of from 25 to 50 hp. For surface finishing on oil mix, the tandem-drive motor grader is usually preferred, although it has a slight tendency to skid, and the wheels dig in on the curves.

The cleaning of pavement surface prior to the application of asphaltic material is ordinarily performed with revolving brooms attached to light wheel tractors. This arrangement is not as satisfactory as a unit mounted on a four-wheel pneumatic-tired trailer, equipped with separate engine for operating the broom. Such a unit can be towed by either a light truck or wheel tractor, and may be shifted as needed without the necessity of tying up a particular tractive unit.

Snow-Removal Equipment—The type of equipment required for snow removal varies, of course, with the particular conditions. It includes one-way speed and reversible push plows, V-plows and rotaries and rotary widener plows. All but the widener units may be truck or tractor-mounted.

There are three distinct types of push plows; two straight blade and the V-blade. One straight-blade type has a reversible blade for throwing snow to either side; the speed plow, also straight blade, has a fixed tapered blade, and throws snow to one side only. The latter is also equipped with adjustable flare boards for increasing the height of the moldboard.

The speed plow will handle 12 to 24 in. of new snow at truck speeds of 12 mi. an hour. It is customary to operate this type of plow with the start of the storm, windrowing the snow to the roadsides, until the storage space is used up, when it is necessary to dispose of it with rotary equipment. Reversible push plows range up to 24 in. in height, and are particularly advantageous in thorough and side-hill cuts. They lack the capacity of the one-way push plow, as 18 in. of fresh snow taxes their capacity at truck speeds of 10 miles per hour. V-plows are capable of handling 4 to 5 ft. of fresh snow at truck speeds of 3 to 6 miles per hour. They are particularly advantageous in maintaining sections subject to drifting, and operate well on steep grades and sharp curves. Equipped with wing plows, they are capable of maintaining sections where the maximum seasonal snowfall does not exceed 9 ft.

Among the several truck-mounted rotaries now available, mention will be made of three. The first type, which can be either truck or tractor mounted, is equipped with dual fan blade rotors mounted each side of a V-plow. It is excellent for both widening and operating against a bank of snow, though its effectiveness in drifts is determined by the height of the rotors, but it is not very efficient in clean-up operations.

The second type is truck-mounted, with an auxiliary engine operating a large blade rotor at the front of the truck, similar in design to the standard railroad rotary. It has great capacity and strength, and excels in the opening of snow-blocked roads. It is not efficient on clean-up or widening operations.

The third unit, an auger-blower type rotary, has worked out very satisfactorily for both widening and clean-up. With a digger attachment, it is now equipped to handle drifts. In fresh snow, this unit will make a 4-ft. cut 8 ft. wide at the rate of ¼ mi. per hour; or a 6-ft. cut, 8 ft. wide, at 1/10 mi. per hour.

The rotary widener, which has an individual engine operating a fan blade rotor, is mounted on a two-wheel rubber-tired trailer, the unit being towed back of a truck or tractor. It is used entirely for widening, and can handle a 4-ft. cut 2 ft. wide at a speed of 2 mi. per hour. It is not particularly successful where the road is in a through cut, or where boulders are apt to be found imbedded in the snow. The rotor can and does cast snow outward for a distance of 50 ft.

SLICE-BAR ATTACHMENT for trucks used to cut down and slope back overhanging snow cuts and so reduce subsequent falls and slides.

AUGER-BLOWER plows are excellent for widening and cleanup operations and with digger attachment will open drifts; this plow is working at Yuba Pass in California.

FOR SHOULDER GRADING tractor graders are preferable and for heavy work tandem-graders with dual tires give the extra tractive power.

Road housekeeping equipment

Besides the operations to improve road structures and service, maintenance calls for a variety of work of a housekeeping character and this calls for a variety of machines and tools. Without detail this equipment is indicated here.

Traffic Striping — The present-day traffic striping machine, as developed in California, is capable of performing five times the amount of work that could be turned out by the old hand-propelled gravity-feed unit. The machine is propelled in front of a 1½-ton two-wheel drive truck, where the operator guides it from a comfortable seat free of traffic hazard. The paint, which is carried on the body of the truck, is power agitated and forced by a gear pump mounted on the truck, through the supply hoses to the spray gun set immediately ahead of the operator's seat. The width of line is governed by two adjustable metal disks which turn by surface friction. Under a recent improvement, this outfit is capable of marking simultaneously two separate parallel stripes having a 3-in. separation between lines. This type of stripe is used to mark the center of four-lane pavements, as well as horizontal and vertical curves of limited sight distance where passing is prohibited.

Roadside Mowing and Spraying—The demand for clean roadsides has done much to improve the horse- and tractor-drawn type of mower as well as those attachments used with light wheeled tractors. A new unit with balloon pneumatic tires is now available, equipped with its own tractive and operating power. It can be operated by one man, while others require two men.

It has been a practice in this state to eliminate roadside growth which during the summer presents a fire menace to the adjacent grain fields, by spraying

early with a 27 deg. gravity diesel oil. The rank growth shortly withers, and can be burned without hazard, while the adjacent grain is still green. As some thousand roadside miles were thus treated, a special pneumatic-tired trailer was constructed equipped with separate engine, pump and adjustable spray bars, which could be attached to any truck tanker. The spray bar can be readily extended, lowered or raised from the operator's platform, while the truck is in motion.

Bridge Painting — The sandblasting, painting and repair of major steel structures, while generally contracted, oft-times is carried on as a special maintenance operation. It usually requires a light transportation truck, compressors, sand chambers, pressure feed paint tanks, spray guns and riveting air hammers. Naturally, the size of the job will determine the size of the compressors. On large jobs it will be found advantageous to have a 105-cu.ft. compressor mounted on a 2-ton, two-wheel-drive truck, as well as a 260-cu.ft. pneumatic-tired, trailer-mounted unit, for operating at different points without the necessity of laying extensive air lines. In general, three sand chambers of 7½-cu.ft. capacity will suffice, and four pressure-feed paint tanks of 7 to 10-gal. capacity should provide enough material for eight paint-spray guns. The pneumatic riveting hammer is required for railing and lattice repair.

Small Tools — Notwithstanding the varied equipment mentioned, there still remains that with which we first began —namely, the pick, shovel and wheelbarrow. They are as essential today as ever, and could be less well spared than any of the devices previously enumerated.

II—Equipment Management

EQUIPMENT used on maintenance work is, in general, state-owned, although it is the practice as far as possible to rent privately-owned equipment such as power shovels, oil distributors and heavy trucks required for seasonal or peak-emergency work; the policy is to purchase only such units as have year-round use or are of a special character not easily rented. This policy is of mutual benefit to the state and private equipment owners, as it avoids the necessity of a heavy capital investment by the state, and provides employment for idle private equipment.

The main disadvantages of using privately-owned equipment are the delays in servicing and parts replacements, and the unfamiliarity of private operators with maintenance operations. As a result of these factors, state-owned equipment is not only generally in better condition, but less delay is experienced in its operation.

Analysis of use

Management of plant necessarily must be based on its volume and cost, the kinds of use to which it is put and the amount of paying work which it performs. In analyzing these items specific cases must be taken and this is done here.

The value of state-owned maintenance equipment in California is about $3,700,000, or some $290 per mile of highway actually maintained. The territory served includes valley, mountain and desert and presents a great variety of conditions and surface types. The surface types maintained may be classified as 2,252 miles of portland-cement concrete, 234 miles of oiled surface-treated cement concrete, 1,364 miles of asphaltic concrete, 2,057 miles of bituminous macadam, 2,788 miles of bituminous-treated crushed rock, 2,404 miles of dust oil, 152 miles of gravel, 1,429 miles of earth and 72 miles of bridges.

The extent to which certain of the more common types of equipment are used throughout the year on this diversified topography and surface is clearly shown in Table I. It represents the average for all districts for a particular type of equipment based on a possible use of 5 days a week, for a 52-week year. The percentage use for each class is the relationship between the actual use to the total possible use. This table also indicates units whose use is purely seasonal. Another interesting record, Table II, is the percentage of maintenance funds expended during the past six years for equipment rental, materials and supplies, service and expense, wages and salaries.

Shop and field servicing

The State Division of Highways, comprising some 14,000 miles, 12,752 miles of which are under maintenance, is divided into eleven districts. Under the present system a large, very well-equipped central shop is maintained at Sacramento, where major repairs, overhauling, remodeling and experimental work is performed for the entire state. Work not handled in the central shop is performed in the district shops, of which there are nine, the needs of the remaining districts being cared for by the central shop. The maintenance of the equipment is financed from a portion of the rental charges.

The equipment department is in charge of the equipment engineer, R. H. Stalnaker, who is responsible to the state highway engineer. Under him at headquarters are the shop superintendent, two assistant equipment engineers, two junior equipment engineers, a chief clerk, and the necessary clerical and shop employees. The district superintendents of equipment, clerical and shop employees also report directly to the equipment engineer.

Headquarters Shops — The central shop consists of a group of permanent, well-designed buildings. The largest occupies some 26,000 sq.ft. of floor space, and in it are also housed the offices of the equipment engineer and his staff. Other buildings provide floor space of 10,000 sq.ft., 8,400 sq.ft. and 6,000 sq.ft., respectively, with an additional 10,000 sq.ft. available for storage. All shops are well lighted, ventilated and steam heated. They include a fully equipped machine shop, blacksmith shop, electrical shop, truck shop, auto shop, paint shop and regular servicing shop.

The machine shop equipment includes such units as 48-in. boring mill, turret lathe, horizontal milling machine, 5-ft. radial drill, small lathes, grinding machines and cylinder grinder. In the blacksmith shop there are large forges, a power hammer, 300-ton hydraulic press, welding outfits, and heat-treating equipment. The electrical shop has complete electrical apparatus for automotive testing, radiator test bench and bank, as well as a battery charging outfit with a large motor generator. The truck shop has connecting-rod rebabbitting machines and main-bearing boring machines. In the auto shop are all necessary facilities for testing automotive engines, a cylinder-boring machine, and full equipment for tire and upholstery work. The paint shop has spray guns, sanders, and electric polishers. All of the usual accessories of a well equipped shop are found, and work of almost any kind can be successfully and economically handled.

District Shops — The district shops are housed in their own specially built buildings, and these, while not as extensive as those at headquarters, are still ample to care for any needed equipment repair in the particular district. The equipment varies quite widely in the several district shops. One of the larger shops has the following equipment: A 16-in. engine lathe, 24-in. shaper, key-slot cutter; small, medium and large drill presses; one arbor press, one garage press, cylinder boring machine, valve grinder, blacksmith forge, power hack saw, 100-lb. belt-driven power hammer, oxyacetylene welding

outfit, motor-driven 6x5-in. compressor.

The main bay in the shop is equipped with a hand-operated 3-ton traveling crane. The shop is also equipped with a connecting-rod aligner, electrically-operated brake-lining machine and facilities for cleaning and painting equipment, as well as the usual assortment of small tools.

Field Service—In most of the districts, traveling mechanics are maintained, each of the crews having a truck equipped with small tools, acetylene welding outfit, supplies such as cap screws, gasket material and a few small parts. These men are used in districts where distances from the shop are especially long, and much time would be lost in moving the equipment in from the field for minor repairs.

In a few instances, local emergency shops are maintained separate from the main district shops. These have limited personnel and equipment, and are designed only to handle minor repairs to equipment in districts remote from the main shop.

Maintenance equipment operators are expected to handle only the simplest repairs, such as changing of spark plugs, brake adjustments, etc. All personnel in the equipment department comes under the provisions of civil service, and the wage scales set up under these provisions compare favorably with those in commercial shops. The headquarters shop maintains a force of about 100 employees, and the number of employees in the district shops varies from 10 to 45.

Equipment purchase and rental

The general policy is to purchase all equipment in the open market and to construct only such units as are not obtainable commercially. In preparing specifications for equipment to be purchased, every endeavor is made to keep bids open to as large a number of manufacturers as possible. However, in particular instances where some trademarked device or machine appears to offer unique advantages, a specific unit of this sort may be purchased for experimental purposes.

The accurate records kept of each individual piece of equipment, showing investment, age, depreciation, total days used, repair cost, etc., clearly indicate the time for its replacement or definite retirement and sale if no longer needed. Every opportunity is given prospective buyers to examine such equipment. The commercial field is thoroughly canvassed for new machines which incorporate the most desirable improvements. In practically every instance the turn-in value of the motor vehicles and tractors to be replaced is applied toward new purchases; other equipment is advertised for sale and sold to the highest bidder. Exact knowledge of the worth of different makes and construction of equipment, from the standpoint of both operating and useful life, makes possible the most intelligent selection in both replacement and new purchase.

TABLE I—NUMBER AND AVERAGE USE OF VARIOUS UNITS OF EQUIPMENT OWNED AND OPERATED BY THE STATE HIGHWAY MAINTENANCE DEPARTMENT OF CALIFORNIA

Type of Equipment	Total No.	Av. Total Days Used	Total Possible Days Use	P. C of Possible Use
1-yd. dump truck, etc.	252	248	260	95.4
1½ to 2-ton, 1½-yd. dump truck	274	227	260	87.3
1½ to 2-yd. dump truck	21	208	260	79 9
3-yd. 3-ton and truck tractors	77	196	260	75.4
3 to 3½-ton, 3½ to 4-yd. dump	26	205	260	79.0
5 to 6-ton, 5-yd. dump	7	150	260	57.5
Compressors	11	131	260	50.3
Graders, 7 to 8 ft.	173	126	260	48.5
Graders, 9 to 12 ft.	3	97	260	37.3
Grader Tractors	127	179	260	68.7
Kettles	220	86	260	33.2
Marking machines	11	84	260	32.4
Mowers	43	55	260	21.3
Snow plows, Blade and V	133	32	260	12.2
Snow plows—rotary, etc.	19	79	260	30.3
Rollers	22	81	260	31.1
Scarifiers	39	44	260	16.9
Shovels	16	187	260	71.8
Wheel tractors	91	157	260	60.3
Track laying tractors	90	161	260	62.0

TABLE II—PERCENTAGES OF TOTAL GENERAL MAINTENANCE CHARGES

Year	Materials and Supplies	Service and Expense	Salaries and Wages	Equipment Rental
1929–30	24.77	4.67	46.78	23.78
1930–31	20.91	8.15	49.49	21.45
1931–32	20.83	7.62	48.71	22.84
1932–33	22.62	6.33	49.46	21.59
1933–34	23.53	8.22	48.65	19.60
1934–35	24.38	7.96	46.68	20.98
Six-year Average	22.84	7.16	48.29	21.71

The establishment of rental rates was at first a matter of more or less arbitrary judgment due to the lack of authoritative data on the use and repair of this equipment. The only known data were the recommendations of the Associated General Contractors, and these were of only general value, as they contemplated use for only a portion of the year and that on construction work where equipment is given the hardest kind of use. Deprived of the benefit of previous experience through lack of records, rates were fixed on the basis of the best judgment to be had, and repair costs were kept from the beginning. The piling up of these data soon furnished the information needed for the inevitable adjustment of the first experimental rates. These first adjustments were for the most part downward, and as the system has year by year made possible better maintenance of equipment and wiser selection of replacements, several more revisions have been made, and all downward.

The basic principle is that each class of equipment must "stand on its own feet." The system is designed to be self-supporting in every respect, its sole source of funds being the rentals charged. The rental rates, therefore, must be sufficient to cover administrative costs, maintenace expenditures and adequate depreciation to amortize original cost, plus a small contingency fee.

The basic control for rental charges and operating costs is the daily reports rendered for each item of rental equipment. In the case of motor vehicles, operators show on their reports the number of hours worked, mileage traveled, gas, oil and grease used, together with special data regarding each individual tire and its wheel location on the vehicle. Similar data are gathered daily in each district for the miscellaneous units of rental equipment other than motor vehicles and these data are forwarded monthly to the headquarters office.

Gas, oil and grease used are a part of the operating cost and are billed directly against the department in possession and are not included as part of the rental charges. Ordinary servicing charges such as cleaning, washing, etc., are treated in the same manner.

Daily rental charges are based on one 8-hr. shift in a calendar day for ordinary maintenance work. Much of the equipment, particularly the smaller units, is placed on a straight monthly rate.

For motor trucks, progressively higher rates are charged as they exceed 8 hours' use and 75 miles travel per calendar day. Also, the rates are increased in cases of extremely hard usage, such as when trucks are used under the larger shovels.

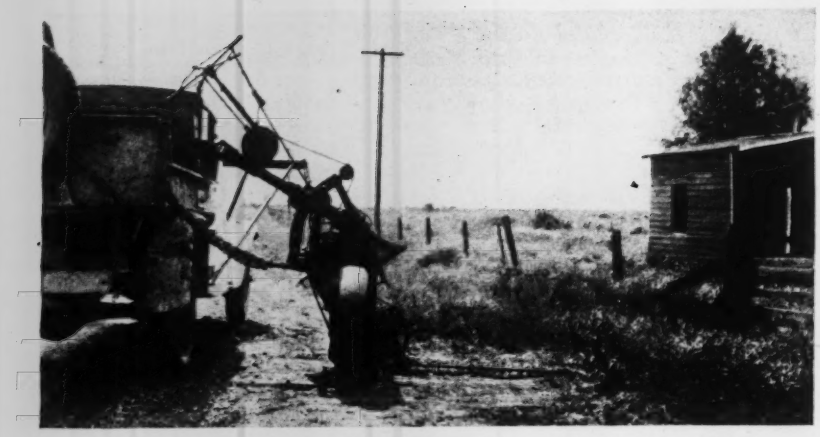
Only portable equipment is included in the rental set-up. Permanent equipment placed in maintenace yards does not come under the jurisdiction of the equipment department.

Small tools and articles of equipment which have a short life are under control of the district engineers, as are all lesser items which can be purchased for $100 or less, such as plows, rooters and small scrapers.

There are occasions when it is advantageous to rent private equipment for certain jobs. This is handled by the district engineers, and not by the equipment department.

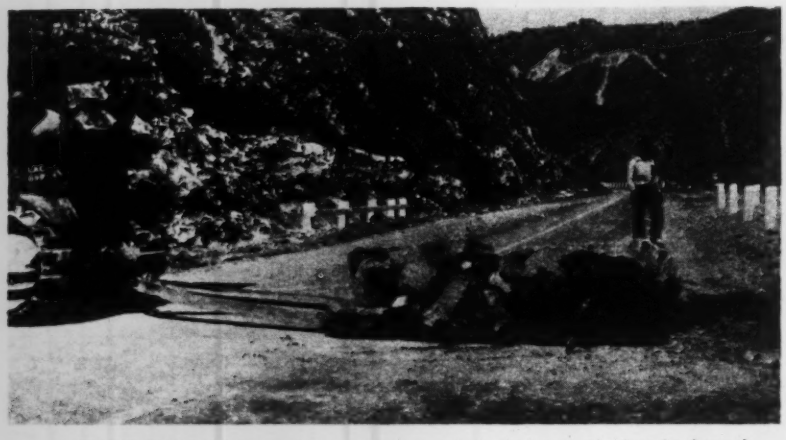
The lands acquired for shops are not considered in the general financial set-up of the equipment department, but shop buildings are treated in very much the same manner as an individual piece of equipment. The financial history of each is kept separately, showing original cost, additions and improvements. Life expectancy is determined and regular depreciation to build up replacement reserve is charged directly to various districts.

The upkeep on shop equipment is included in the shop overhead costs, and



SPECIAL MACHINES for roadside mowing are built; this view shows a convenient mowing attachment to a motor truck.

REPAIR TRUCK used by traveling shop mechanics in servicing equipment on operations beyond economical return distance to district shops for minor repairs.



A STONE BOAT rigidly coupled to a tractor can be backed over a bank to be dumped.

is thus reflected in the rental charges.

While the distribution of equipment was originally the chief function of the equipment department, with the passing of time the rental system has been established and perfected to such an extent that distribution has now become almost automatic in its operation and calls for only a minimum in the way of conference between department heads. Beginning with the allotment of federal war surplus, the several districts gradually collected a stock of needed equipment, so that by the time the rental system was adopted they were each fairly well outfitted to meet all ordinary demands. In fact, there were instances uncovered where equipment had been on hand and unused for long periods, and this natural disinclination to part with equipment once acquired was one of the main reasons for the inauguration of a rental system.

A minimum charge of ten days' rental a month was first set up. This was assessed against all equipment so long as it was in possession of a district and not released for transfer. Later this minimum was reduced to five days, which is the present charge. All equipment on monthly rate is charged to the district as long as it retains possession. In this way, districts may now retain equipment so long as they feel justified in paying this minimum rental. Otherwise, they release it to the equipment department and it then becomes available for transfer. Replacement of worn out or obsolete equipment is provided for by the depreciation reserve portion of the rental charges, which reserve has been set up for this purpose. When additional units are requested by any particular district, if possible the request is filled from the available transfer list. If this cannot be done, new equipment is ordinarily purchased, payment to come eventually from rental charges which the district must necessarily pay. The depreciation reserve as set up and included in rental charges is sufficient only for replacement of existing equipment, and if for some reason additional equipment is needed due to increased traffic or more mileage being placed under maintenance—as in 1933 when many thousands of miles of road were added to the State system—budget appropriations are set up for the purchase of new equipment.

As a safeguard against over-equipment of the system or any portion of it, the maintenance engineer is regularly supplied by the equipment department with a list of unreleased equipment on which the five-day minimum rental is being charged but which records show is being used less than this minimum number of days. In this way, inquiry may be made as to possible release of such equipment for transfer or other disposal. In addition, studies are made to determine whether the average use per year of equipment indicates the advisability of reducing the inventory as a whole or in any particular category; or whether improvements in system of distribution may make possible a reduction in the total number of units.

Accounting methods

The definite and accurate cost of any job is not known unless proper charges are made against it for whatever equipment has been used. Furthermore, the keeping of exact upkeep and depreciation costs has in many instances shown beyond the possibility of argument that certain equipment, which widespread opinion had considered quite efficient, was in reality so expensive that it was quickly discarded. To make possible exact accounting control over the im-

mense mass of detail inherent in a system combining perpetual inventory of such a wide range of materials and parts, with precise cost data on individual units, bookkeeping machines are installed in all shop offices. Headquarters office the final control point of all accounting, is likewise fully equipped with all necessary bookkeeping machines. During their use, many very clever innovations have been devised in the printed forms used, which greatly increase the efficiency of the system.

Each new piece of equipment is given a number and its depreciation rate and rental rate is established on the basis of previous experience. Depreciation is assessed on a straight line basis until the unit is replaced or discarded, regardless of its book value at the time of retirement. The debit or credit adjustments made for different groups of equipment form the basis for new depreciation rates. An individual record form is prepared showing all details, such as a description of the unit, date, cost, depreciation rate, rental rate and location. On this form is kept the life history of the unit, its original cost, additions, transfers, days used, rentals charged, quarterly depreciation, and expenditures for repairs and for administration. This record is kept in headquarters office and entries are made monthly from the reports submitted by the district shops. Totals are regularly accumulated so that there is at all times an up-to-date financial statement of each item of equipment. A quarterly consolidated report is also made, by use of which any interested administrative officer may at a glance read the story of equipment operation and costs.

District-shop office records show in detail all information regarding equipment located in the respective districts, and these data are accumulated and transmitted in consolidated form to headquarters office at the end of each month. Individual job orders for all work are issued and all charges for materials and labor are made to these orders. The perpetual inventory system is used for all supplies, making complete an accounting system whereby all essential data regarding the entire equipment are available at any time.

The value of such consolidated, up-to-date statistical data covering all phases of maintenance equipment cannot be over-estimated. How much there is, where it is, whether idle or working, what its cost and performance have been —these are data without which the job of maintenance of the highways cannot be well administered.

State Road Organization

Maintenance is road improvement, not merely upkeep, and technical personnel is more important than skeleton setup—Engineers in immediate charge are the key men

By W. H. Root

Maintenance Engineer, Iowa State Highway Commission, Ames, Iowa

FOR THE PURPOSE of this discussion I shall confine my remarks to those functions of the maintenance department which are truly road and bridge maintenace. State maintenance departments have become the catch-all for various necessary highway department activities, some of which are directly related to maintenance and some of which have been assigned to maintenance departments simply because these departments have had the necessary organizations to handle the additional work.

These correlary activities are too varied to be discussed here, and the subject proper is here further limited by considering primarily maintenace personnel as the flesh and blood of organization of which district arrangement and charts of sequence of authority are skeletons. The district and division arrangement in Iowa and the Iowa organization chart are shown by accompanying illustrations; every state has some such arrangement adapted to its road distribution and management policies. In a broad way district subdivision of maintenace under central state authority is the universal system of organization. The important fundamental of organization is not its graphic form but its personnel. This will be discussed here.

The problem and the duty

Assuming then that the chief duty of the maintenance department of a state highway organization is to maintain the state highways and bridges, let us first inquire as to what is meant by the word "maintain." The accepted dictionary definition of road maintenace "To hold or keep the road in the particular condition in which it was when taken over for maintenance" is entirely too narrow for modern highway practice. State highway officials and the public in general expect the maintenance department to keep the roads from deteriorating and, in addition, gradually to remedy and eliminate the mistakes of original design and construction so that over a period of years maintained roads will be actually improved and made safer. This is as it should be. A maintenance department that is worth its salt will be continually on its toes to increase the efficiency of the roads maintained and to point out to the other departments ways and means of improving design and construction.

The employees of a state highway maintenance department can be divided into two classes: Those who work and those who do not work or, more charitably, those who do the manual labor and those who supervise and plan the work. I know of no type of work where closer cooperation from top to bottom is necessary than in highway maintenance. Contrast the design and construction of a road with the maintenance of the same road after construction. Volumes have been written to guide the designer and construction engineer in his work but the maintenance engineer must make his own way. Highway maintenance is not an exact science. Every type of road in every different location presents different maintenance problems. It is true that the maintenance should be governed by general, well-established principles but

WINTER'S BEAUTIFICATION of a division maintenance engineer's office and garage; out of thirty of these headquarters deployed the forces that fought Iowa's blizzard snowfalls of the past winter.

in the application of those principles practically no two problems can be solved alike. New methods of applying maintenance principles to specific maintenance problems are continually being developed by the supervising force and quite as often by the workers themselves.

The best organized maintenance department is the one that most efficiently seeks out and makes available for the entire department new and practical maintenance methods developed by its own employees or by those of other states.

Division heads are the key men

A good maintenace department must have good workers and good supervisors. It is not fair to say that any particular group in the department is more important than any other. I have always felt, however, that the division maintenance engineers, spending their full time on maintenance work and being directly and personally in contact with the individual maintenance problems, are the real backbone of the state maintenance organization.

These division maintenance engineers (or call them what you may) should have under their care not more than 250 or 300 miles of state road. The mileage which can be properly supervised by a division maintenance engineer will, of course, vary with the type of road, compactness of territory and other factors. This mileage should never, however, be so great as to exceed the division maintenance engineer's ability to supervise carefully all maintenance operations, including snow removal.

REPORT OF ANNUAL COSTS OF GENERAL HIGHWAY MAINTENANCE

(General Highway Maintenance does not include reconstruction and additions or betterments)

I. Surfacing		
1. Patching	1-a	Labor
2. Joint and crackfilling	2-a	Materials
3. Dragging	3-a	Equipment
4. Base and sub base repairs	4-2	Overhead
5. Retreatments for all Ca. Cl. 2		
6. Other state classifications		
II. Shoulders		
1. Patching	1-a	Labor
2. Dragging	2-a	Materials
3. Sodding	3-a	Equipment
4. Retreatments	4-a	Overhead
III. Drainage		
1. Ditches	1-a	Labor
2. Drains	2-a	Materials
3. Culvert Cleaning	3-a	Equipment
	4-a	Overhead
IV. Structure Repair (Incl. bridges not over 20' span)		
1. Bridge and culvert	1-a	Labor
Guard Rail	2-a	Materials
	3-a	Equipment
	4-a	Overhead
V. Roadside		
1. Grass and weed cutting	1-a	Labor
2. Removal of debris	2-a	Materials
3. Highway beautification	3-a	Equipment
4. Cuts.	4-a	Overhead
5. Fills		
VI. Traffic Service		
1. Highway markers	1-a	Labor
2. Gude line painting	2-a	Materials
3. Snow removal	3-a	Equipment
	4-a	Overhead

The division maintenance engineer should be a graduate or at least a registered engineer. He should rank with the highest class resident engineer on construction. It goes without saying that his appointment should be strictly on a merit basis and free from politics. His tenure of office should be continuous during good behavior. The fact should not be overlooked that the usefulness of a division maintenance engineer increases as he gains experience and familiarity with his district.

A division maintenance engineer should first of all, be practical. He should be well grounded in engineering fundamentals but he need not be expert in details of design. By being practical, I mean that he must be able to diagnose accurately a road failure, give quick first aid treatment and then promptly cure the trouble.

A further important qualification is personality. To the farmers along the state highways and to the thousands of other local citizens, the division maintenance engineer is the state highway commission. Most of these folks will never come into contact with any member of the highway commission and their approval or disapproval of the acts of the commission will largely depend on whether or not the division maintenance engineer has carried out the maintenance program in their locality in a satisfactory way. Reams might be written upon the public contacts of the division maintenance engineer, but for this paper let it suffice to say that he should join the local chamber of commerce, be a member of the school board, maybe, and in short, become one of the community in which he works. He should never be too busy to take time to listen sympathetically to the kicks and suggestions of the local men and women.

The division maintenace engineer should have discipline among the men

under him. He should not, however, rely upon top-sergeant-discipline enforced arbitrarily; his discipline should be that of loyalty. If he has worked up among his men the proper esprit de corps there will never be any question about his men standing firm in an emergency. If, when it is 10 to 20 deg. below zero and the wind is blowing and piling the snow over the snow fences into the highways, his men are willing to man the snow plows for 18 or 20 hours at a stretch with only an occasional few minutes out for a cup of hot coffee and a sandwich, then the division maintenance engineer may know that he has the loyalty necessary for a division to function properly.

The duties of the division maintenance engineer are closely connected with the actual maintenance work. He should direct the foremen in the routine and less extensive maintenance job. Before undertaking a large or unusual maintenance job which is not an emergency matter he should consult his superior officer. He should supervise the work of the mechanics and make sure that all equipment is promptly repaired after breakdowns and that it is kept in first-class operating condition.

Repair parts and all incidental equipment and material items should be purchased by the division maintenance engineer after receiving competitive quotations. He should not be expected or allowed to purchase large items of equipment; neither should he be permitted to enter into contracts for extensive maintenance work. The division maintenance engineer should have a well equipped office with a full time clerk or stenographer, and perpetual inventories of all maintenance material and equipment should be kept in this office. All bills against the state for repairs, material or equipment used within the division should be checked, the costs distributed and the claims approved by the division maintenance engineer.

I have dwelt somewhat at length on the qualifications and duties of the division maintenance engineer, the backbone of the department. Let's not overlook the loyal men under him who, after all, actually do the work. In this class are the pick and shovel men, machine operators, mechanics and foremen. All of these men should be carefully picked by the division maintenance engineer for their ability and physical fitness alone and they should be retained as long as they are proficient and loyal. Disloyalty of any workman should not be tolerated under any circumstances. The work of these men should be watched and studied carefully and advances in rank and pay should be made when they are deserved.

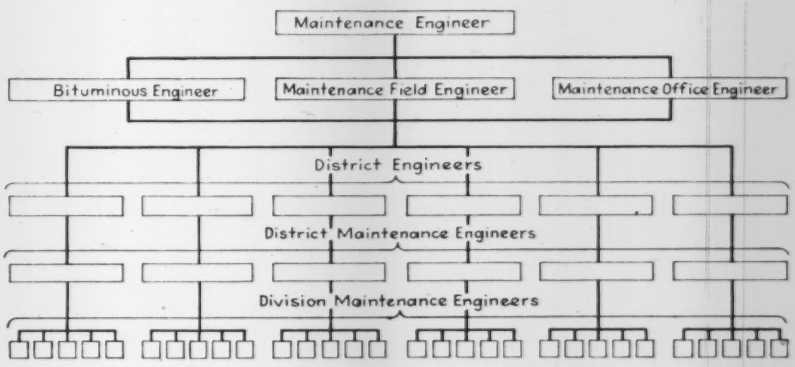
General organization policy

Most states are divided into six to ten districts for the administration of the state highway work. Each such district should have in it a maintenance man who spends all of his time planning, supervising and coordinating the work of the division maintenance engineers. Suppose we call this man a district maintenance engineer, keeping in mind that district as used here is a larger unit than division. In the writer's state, for example, the average division contains three or four counties while each district is made up of a group of fifteen to seventeen counties. This district maintenance engineer should have considerable responsibility in the allocation and accounting of the maintenance budget. In other words, the division maintenance engineer should be primarily interested in doing the maintenance work and if, for economic reasons, it is necessary to slow him down this should be the duty of the district maintenance engineer. These district maintenance engineers should be supervised by the central office of the maintenance department but this supervision should be exercised through the chief district engineer. This will keep the lines of authority and responsibility intact.

A state maintenance organization would then be (1) the state maintenance engineer and his principal assistants working through the chief district engineer; (2) the district maintenance engineer planning and supervising the work of the division maintenance engineers, and (3) the division maintenance engineers performing the maintenance work with their corps of laborers.

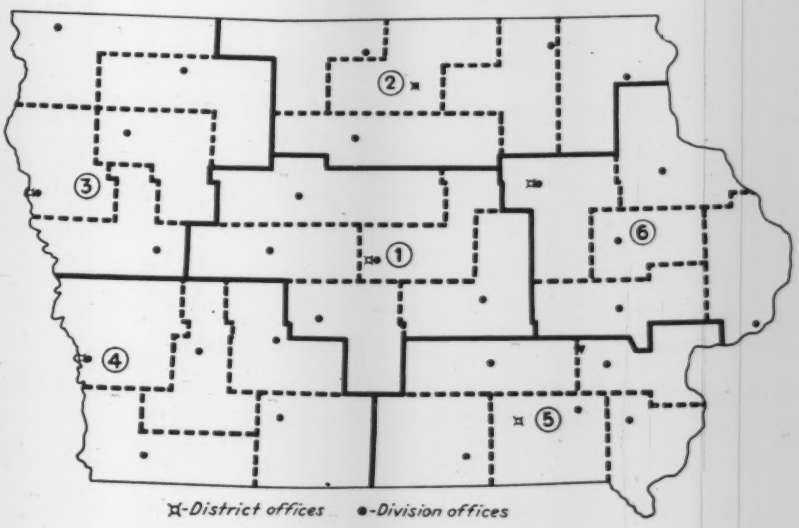
Contracts and purchases of important items of equipment, large material orders for extensive maintenance work should be awarded and signed by the state highway commission or commissioner. Public bids for such contracts should be received and tabulations made by the state maintenance engineer who should also be responsible for the specifications for such items. The maintenance engineer should file a complete report of each letting with the commission and he should make definite recommendations with reference to contract awards.

A paper on maintenance organization



SIMPLE AND DIRECT transmission of authority is indicated by this maintenance organization chart for Iowa.

IOWA STATE ROADS are grouped for maintenance into six districts and thirty divisions bounded as shown by this state map.



would not be complete without something about maintenance accounting. The important thing about this is that it should be as nearly uniform as possible in the different states. I do not think the exact plan of acounting is important; it is essential, however, that all states report their maintenance expenditures under the same fundamental classification. After years of study of this problem I am convinced that the layman will never be able intelligently to compare maintenance costs as reported by one state with those reported by another. However, I do have high hopes that highway engineers will eventually be able to make fairly intelligible comparisons between states. First of all, it would be an advance step if every state would carefully separate items of maintenance proper from items of betterments. Most states do this now but some are still lumping these items together in their annual reports in such a manner that no one not in direct contact with the work can separate them.

The Bureau of Public Roads has set up a classification of maintenance expenditures to be used in reporting the maintenace of certain sections of federal-aid roads by various states. This set-up is not perfect. In fact, I presume that almost every state would be able to suggest changes which would make it more workable for the particular conditions in that state. In my mind, however, this classification has been well thought out and it seems to me that it has more reason for being adopted as a standard than any other plan which might be set forth by a single state or group of states. I would like to see every state in the union adopt the Bureau of Public Road's classification as a standard for reporting their state maintenance expenditures. The classification is briefly as shown in the accompanying tabulation. Its advantage is that it will bring uniformity in reporting, which is the first step in being able to compare maintenance costs.

County Road Organization

County organization for road upkeep involves every nicety of business management and skill of personnel called for in state system management

By O. S. Hess

Engineer-Manager, Kent County Road Commission, Grand Rapids, Mich.

WHILE THERE IS a wide variation in the methods of organizing and directing the maintenance operations of county highway departments, it is possible to outline the general plans which have proved successful in many counties over a long period of time. County highway organizations are about as well developed in Michigan as in any other part of the country, and because of the writer's familiarity with Michigan county work, this article will follow Michigan's practices closely. The maintenance organization of Kent County is quite similar to that of many other counties, which are generally considered by highway officials as being successfully operated counties. While the following remarks and information will apply to Kent County specifically, it should be kept in mind that a great many counties throughout the country and particularly in Michigan, manage their road maintenance in much the same manner.

Engineer-manager plan

Kent County is operating under what is generally known as the engineer-manager plan. There are three county road commissioners appointed by the board of supervisors for six-year staggered terms. Every two years one of the three commissioners must be either replaced or reappointed. The engineer-manager, who must be a registered civil engineer, is employed by the road commissioners at such salary and for such period of time as may be agreed upon by the commission and the engineer. The road commission operates as an administrative body only, and the execution of policies and programs which have been decided upon is left to the engineer-manager. He is responsible directly to the road commissioners and the entire operating organization is responsible to him.

There are some very decided advantages to the public in such a system. In the first place, the working organization is usually free from politics; and in the second place the policies and wishes of the county road commissioners are more easily and efficiently carried out by working through one head, rather than several department heads. This also fixes responsibility definitely so that there is little opportunity for confusion in the matter of carrying out orders. By having all of the county highway activities headed up by the engineer-manager, there is also a better opportunity for the proper correlation of the various department activities. This also results in better service to the traveling public as maintenance and construction operations are dove-tailed in such a manner as to give the maximum service, regardless of how it might affect any particular department. In other words, there is no opportunity for department heads to dodge responsibilities. Every activity definitely belongs to some particular department and must be executed by that department. There are department heads for construction, maintenance, equipment repairs, office management, and forestry, and each department is directly responsible to the engineer-manager. All of these departments have something to do with county highway maintenance in one way or another. The actual execution of the maintenance work, however, is handled largely by the maintenance superintendent. He is assisted by a number of district maintenance superintendents as will be more fully explained later.

District division of work

Kent County is made up of 24 townships, each 6 mi. square. The county is a rectangle, 24 mi. wide by 36 mi. long, the long dimension being north and south. There are 2,230 mi. of highways in the county, outside of incorporated cities and villages. This mileage is made up as follows: State trunk line system, 200 mi., largely paved; main county road system, 492 mi. about 25 per cent paved, the balance having gravel surfaces; township roads recently taken over by the county, 1,211 mi., largely unimproved; platted streets outside of incorporated cities and villages, 327 mi., about 50 per cent im-

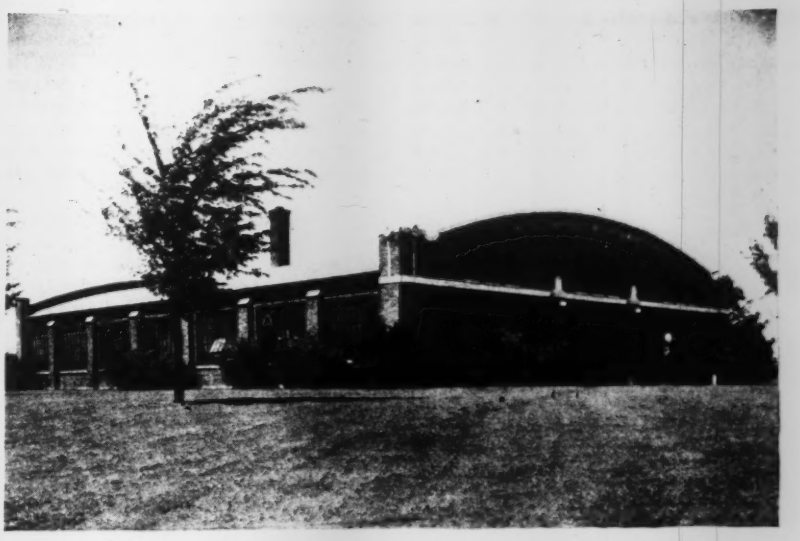
proved with gravel surfaces. All of this mileage except the 200 mi. of state trunk lines is under the jurisdiction of the county road commission, and it is therefore necessary to organize men and equipment to maintain a little over 2,000 mi. of roads, only a small portion of which has been improved with hard surfaces.

As Kent County lies in the snow belt it is necessary to organize for fast winter maintenance as well as for the usual summer operations. To handle the necessary work on this large mileage of low-type surfaces, a large amount of equipment is necessary. Many years ago it was discovered that money and time could be saved by working out plans which would eliminate unnecessary travel of equipment from its base to the point of operations. Therefore to cut costs and place the working organization closer to the point of operations, the county was divided into six maintenance districts.

Roughly, each district covers the roads in four townships, and the mileage in each district averages about 500 mi. Each district is also properly equipped with a garage building which is the headquarters for the district superintendent together with his men and nearly all of the equipment which operates in the district. The central plant is located in the city of Grand Rapids, and this also serves the district in which the city of Grand Rapids is located. The other five garages are all located in cities or villages about the county.

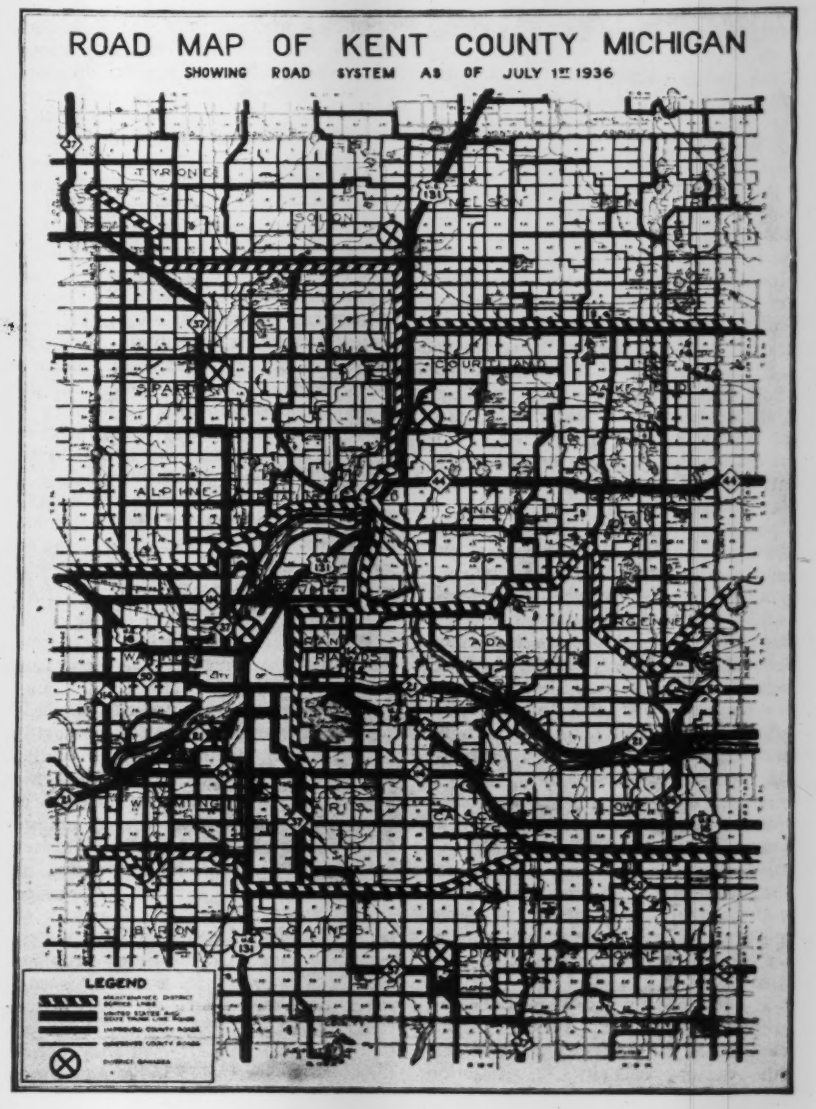
There is a decided advantage in locating the headquarters plants in this manner as it makes it possible to obtain water, electric light and power, police and fire protection, and suitable living conditions for employees. The district garage buildings fully equipped cost about $25,000 each, but the saving due to the elimination of unnecessary equipment travel repays the entire investment in a few years. In addition to this, the service to the public is very much improved because of the time factor involved in carrying out certain classes of maintenance work.

It was also found that a county-wide maintenance organization set up in this manner was much more easily and speedily handled. All of the district superintendents are, of course, responsible to the maintenance superintendent and receive all of their instructions and orders from him. There are a few maintenance operations which do not warrant a complete organization of equipment and men in each district. These operations are handled by what is ordinarily termed gang maintenance crews. This is usually the case where one set of equipment together with one crew of men is sufficient to cover the entire county. Such gangs operate out of the central plant but are usually responsible to the district superintendent of the district in which they are working. In the case of certain betterment



A DISTRICT GARAGE provides each of the six maintenance superintendents of Kent County with headquarters for men and equipment.

COUNTY ROAD MAP showing boundary lines and road classifications.



or light construction work which is handled from time to time by the maintenance department, the crews are directly responsible to the maintenance superintendent and the district superintendent in these cases acts only in a cooperative manner. This type of work, however, is not the usual thing and may be considered as more or less special.

Equipment management

The maintenance work in Kent County requires the use of about 60 motor trucks together with many automobiles, tractors, graders, rollers, etc. To keep all of this equipment operating properly it is necessary to have a well worked out system for repairing and caring for equipment. This has a very important bearing on the efficiency which may be obtained on maintenance work and also on the quality of service which can be furnished to the public, particularly during emergencies.

The system followed in Kent County places the responsibility for this work on the shoulders of an equipment-repair superintendent. He is located at the central plant in Grand Rapids and all of the major repair work is handled at the central plant. This plant is equipped with a machine shop, forge, acetylene and electric welding outfits, repair shop, stock room and other incidentals necessary to a complete plant for the repair of the types of equipment used on county maintenance work. All of the employees at this central plant are employed by and are responsible to the equipment-repair superintendent. Each district garage is supplied with one competent mechanic who works under the supervision of the district superintendent. It is the duty of this man to take care of the necessary oiling, greasing, and all minor repair work on the equipment operating in his district. For most major repairs, however, the equipment is transferred to the central plant for attention.

The old saying that "a stitch in time saves nine" applies 100 per cent to the care of equipment. Following up this idea a plan has been worked out whereby all of the motor trucks go into the central plant for a thorough inspection and check-up every 60 days, regardless of what repairs may have been made in the meantime. At the time of this check-up all defects which can be found are corrected. At this time also the truck is given another coat of paint if it is needed. This, however, only occurs about once a year. Of course the trucks are not all checked at the same time. A regular schedule has been worked out so that this results in a continuous operation throughout the year. It has been found that this periodical check-up prevents a lot of trouble and saves a great deal of money.

The equipment repair superintendent has complete authority over all repair work done at the central plant and acts in an advisory capacity in connection with repair work carried out at the district garages. The district maintenance superintendents have become very important links in the county maintenance chain. Each district superintendent has practically complete authority over the maintenance operations in his district. He hires and fires men practically at will, being limited in this respect only to certain fixed wage rates which he may pay for different classes of workers. The system which has been worked out for handling routine maintenance has been followed so many years that the district superintendent is capable of handling all such work without any special instructions from his superior, the maintenance superintendent. In regard to anything not following the regular routine, however, he receives his instructions from the maintenance superintendent. There is often considerable special maintenance work being carried on which requires special crews usually under the district superintendent.

As gravel surfaces predominate in the Kent County road system it is necessary that large quantities of screened and crushed gravel be produced from local gravel pits for maintenance purposes. The county owns several portable plants and these are moved from one pit to another, producing and stock-piling from five thousand to ten thousand cubic yards of material in a place. Wherever these plants are located the crews are under the direct supervision of and responsible to the district superintendent. As a result of producing stock piles of material at many locations in this manner, there is usually about 100,000 cu.yd. of material in stock at all times. The material is taken from these stock piles as needed for the proper maintenance of the gravel surfaces. Much of this gravel production work is handled by contract. This is done wherever there appears to be a cost advantage to the county. In these cases the work is let to a contractor who uses his own equipment and produces the material under the supervision and inspection of the engineering department.

Personnel management

It is perhaps appropriate that something be said regarding the selection and promotion of men. The Kent County maintenance payroll usually includes about 200 men and the proper selection of these men together with the method of promoting the better qualified men has an important bearing on the efficiency obtained. The county maintenance superintendent reached his present position after having come up through the ranks, his last previous position having been that of a district superintendent. Likewise the district superintendents have been promoted from positions as foremen of special gangs or crews where they had proved their worth. Before having been appointed as special foremen they had in most cases been outstanding as equipment operators or in some way had shown their special value. In this way every man in the employ of the road commission has some incentive to work hard and better his position. If a man is ambitious and really tries to get ahead he has a good chance of climbing up to better positions as he develops. The chance for promotion is a great incentive for all employees to do their best and this naturally results in the accomplishment of more work and better efficiency.

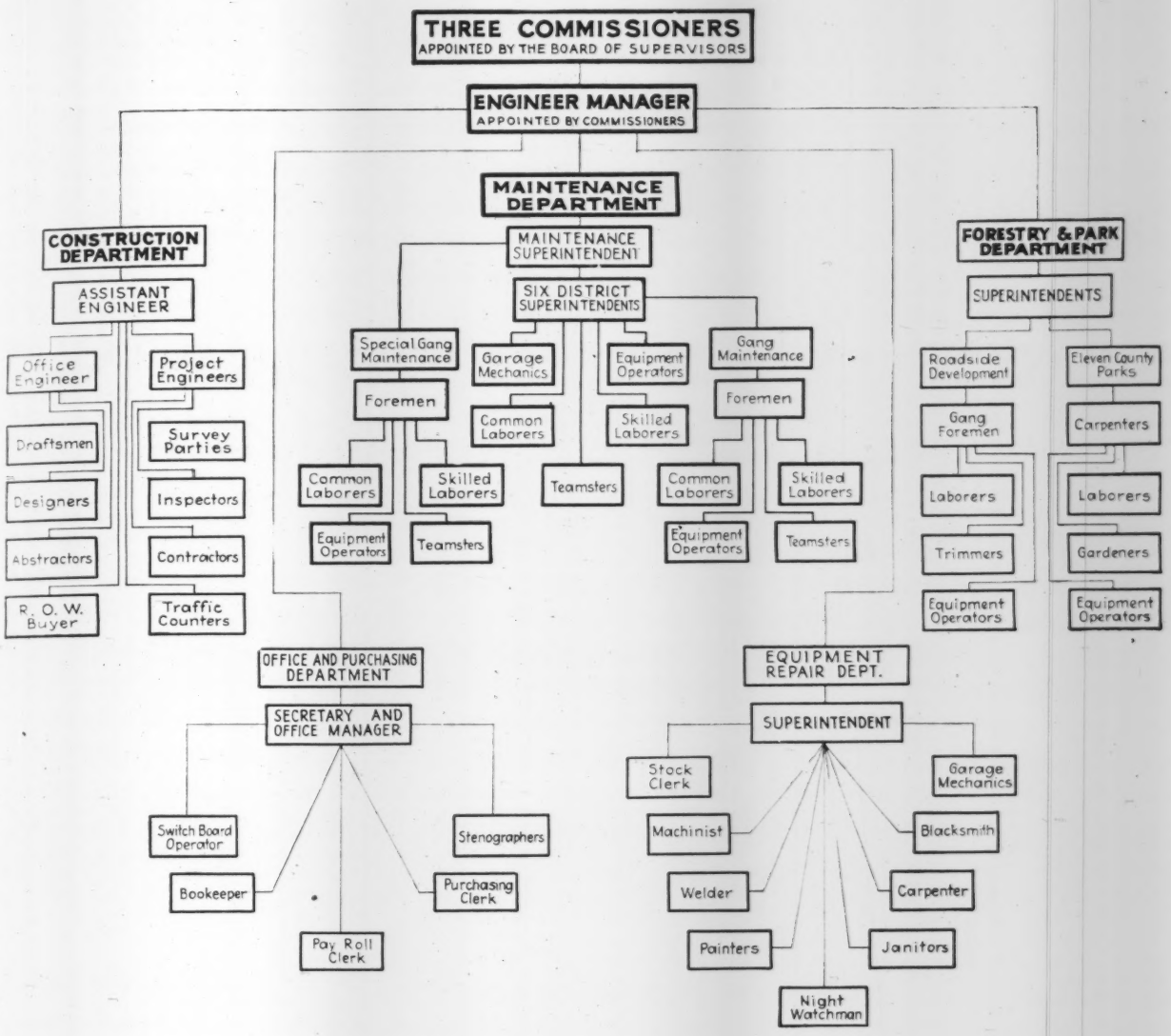
The Kent County highway organization is featured by what we call the Number Two man; for every department head and district superintendent there must be a man who can take his boss' place when the latter is on a vacation or off the job because of sickness or other reasons. The Number Two man, or substitute, as he is sometimes called, steps in and does his best to fill the position during the absence of his superior. These men are selected because of their proven fitness for the job and are considered the top man in each department or division. This system furnishes an opportunity to train men who will be in a position to fill vacancies later. It also provides a means by which the value of these men may be measured, thereby eliminating the possibility of making serious mistakes in appointments later on to fill vacancies which may occur suddenly.

Work methods

In the case of betterment work or light construction which is sometimes handled by the maintenance department, it is worthy of mention that there is close cooperation between the engineering or construction department and the maintenance department. Such betterment work is not carried out haphazardly by foremen who guess at line, grades, etc.; all is properly planned and followed up on the job with the necessary staking, inspection, etc., in a manner similar to that being followed on contract work.

A large share of the gang maintenance work consists of the construction of bituminous surface treatments and retreads using gravel surfaces as a base. It has not yet been found practicable to handle this particular type of work by contract. This is probably due largely to the unfamiliarity of road contractors with this particular kind of work and it is quite likely that as time goes on the contract system may profitably be used. At present this work is organized as a function of the maintenance department and is working out very nicely. The inspection of materials, staking of lines, grades, etc., is handled by the engineering department in a cooperative manner.

The maintenance of culverts and bridges presents a distinct problem which requires special attention. There are literally thousands of drainage structures in the county ranging from 10 in. circular culverts to river bridges 600



ORGANIZATION CHART showing sequence of authority and division of duties of the personnel of the Kent County highway department.

it. long. The ordinary casual inspection made by the district superintendent as he drives over the roads would not disclose many of the defects until failures had brought them to his attention. Here is another case where "an ounce of prevention is worth a pound of cure." With this in mind, our bridge engineer makes an inspection of all drainage structures once a year and makes a record of the condition of all structures. This inspection immediately brings to light any repair work requiring immediate attention and by following up these immediately many expensive failures are prevented.

As a matter of practical handling, the maintenance work on culverts and bridges is divided into two classes: First, the kind of work which can be conveniently handled by the district superintendents using ordinary labor and equipment, and second, the type of work which requires special gangs and special equipment. The latter classification usually involves the larger structures and particularly old steel river bridges. Many of these structures have been reconstructed and brought up to present day loading requirements by using the arc welding process on the steel work and by placing new floors having smooth surfaces and proper load carrying capacities. These jobs also always include painting. All such work must, of course, be carefully planned in advance. This is handled by the engineering department and detailed plans for the work are always available before the jobs are started; also the work is always closely followed by a competent bridge engineer as it progresses. In this way a great many old steel structures which had been considered just about obsolete have been reconstructed and placed in first class condition, most of them being placed in better shape than when first constructed.

The above outline of highway maintenance work in Kent County is a good picture of the manner in which the work is being handled. One thing, however, which has not been mentioned and which is quite important to the traveling public is the 24-hr. service which the maintenance organization furnishes. It is the duty of the maintenance superintendent and his district superintendents to be on the lookout for emergencies at all times. These emergencies are such things as snow storms, sudden sleet and ice conditions, wind storms which blow trees across the road, cloudbursts and floods which wash out culverts and sections of road, and many other items of this sort which might happen day or night. It is the responsibility of the maintenance department to meet any and all of these conditions at any time and to meet them quickly. Here again the divison of the maintenance work into districts plays a very important part. Such emergencies sometimes exist in only one or two dis-

tricts at the same time. Many times the district superintendents have taken care of the emergency conditions before the maintenance superintendent or the engineer-manager has learned of the condition.

At such times the maintenance employees come in direct contact with the traveling public and the situation often calls for considerable diplomacy. The maintenance employees of the county have been taught to treat the traveling public with the utmost courtesy and respect even when the travelers do not reciprocate in like manner. Prompt attention to emergencies and courteous treatment of the public are two things which are invaluable in any highway maintenance organization. Without these attributes the county road commission would soon fall into disrepute with the public and this would eventually result in either a change of road commissioners or in loss of revenue for road purposes or both. After all, the highway program is sold to the public and remains sold largely because of the activities of the maintenance organization and the manner in which the public reacts to the service furnished.

Cracks and Sinks in Concrete

Filling cracks, cuts and joints, and raising sunken slabs are still the main concrete maintenance tasks and still present unsolved problems.

By Alexander W. Muir

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THE INTRICACY of the problem confronting the maintenance engineer in maintaining a concrete pavement depends largely on the skill of the designing and constructing engineer and that of the contractor who constructs the pavement. If sound principles of engineering are used in designing the pavement and these principles are so applied that the pavement is adequate to the volume and tonnage of traffic which it must carry, if first-class materials are incorporated in the work, and if inspection and workmanship are good, the problem is a comparatively simple one. If, however, any one or more of these basic elements is lacking an inferior pavement will probably result, and the problem of maintenance will become that much more difficult and costly.

Maintaining concrete pavements might, therefore, reasonably be considered to divide into maintenance of first-class pavements and maintenance of inferior pavements, although some of the problems are naturally common to both. Setting aside this differentiation the operations of maintenance are: (1) filling joints and cracks; (2) repairing surface defects, broken-down areas and public utility openings; (3) repairing settlements and (4) surface treatments.

Filling joints

PRACTICALLY all modern concrete pavements are constructed with transverse joints and many of them with longitudinal joints. There is, of course, a wide variation in spacing these joints, and in the design and materials used.

The most commonly-used material for both joints and cracks is some form of bitumen. Both tar and asphalt have been used and both have their earnest adherents. What the characteristics of the bitumens shall be is dependent upon several factors: a large wide joint will permit the use of a material of heavier consistency than will a narrow, crooked crack or a narrow joint. In any case, the material must be so designed that it will be stable under the highest temperatures, and tough, rather than brittle, under the lowest temperatures prevailing in the locality in which it is to be used. These two somewhat contradictory requirements make it necessary to select a material with great care. In our opinion, there is still room for further research on such materials and improvement in their character. Recently certain new joint materials have come into use, have been adopted by some authorities and are strongly recommended, but their use is still, in a measure, experimental.

Joints and cracks should be kept sealed, so far as possible, under all weather conditions, to prevent the infiltration of moisture to the subgrade. They should not, however, be kept overfilled, as this creates bumps in the surface, which cause unpleasant riding and, under heavy-tonnage traffic, impose needless and damaging impact stresses on the pavement.

Before any joint or crack is filled it should be thoroughly cleaned and all foreign materials carefully removed. One of the most successful methods for removing dirt and other foreign materials is a high-pressure air jet. There has been a rather limited use of cold joint-filling material, such as asphalt emulsion. With such material it is not absolutely essential that the joint or crack be thoroughly dry. Where hot materials are used, however, it is extremely important that the joint or crack be free of moisture. This is particularly true where hot asphaltic materials are used, as the presence of moisture will result in "foaming" and the consequent formation of voids in the material. It will also prevent proper adhesion to the sides of the crack or joint and thus permit moisture to enter.

A simple and fairly successful method for drying out cracks and joints is to pour gasoline into them and ignite it, permitting it to burn off. This serves to dry out any moisture which may be present, heats up the edges of the pavement and also heats any old bitumen which may be present, so that the new bitumen will more readily adhere to it. Another method is the use of a common hand torch, using kerosene as a fuel. It is not, in our opinion, possible to use too much care in the proper preparation of the joint or crack before the reception of the bituminous material.

The proper preparation of the material is almost equally important. Insufficiently-heated material produces unsuitable consistency and probably does not reach all the voids in the joint and crack that might be reached, owing to the fact that the lower temperature of the pavement chills it before it has reached

its proper place. Overheating, in turn, may burn or coke the bitumen, with the result that its life is destroyed and all the careful preparation of the crack or joint and the labor of application will be lost. The heating kettles should, therefore, be provided with accurate thermometers; the personnel handling the heating should be definitely instructed as to the temperature to which the material is to be heated, and sufficient supervision should be provided to assure adherence to the instructions.

Scaling and cuts

ONE of the most common defects which has developed in concrete pavements in many localities has been scaling of the surface, frequently followed by raveling and disintegration of the pavement beneath. In some cases merely a thin shell has peeled off, leaving sound concrete beneath. In such cases it may be unnecessary to take any steps for the protection of the pavement. Scaled areas should, however, be carefully watched for signs of further disintegration, and the necessary action promptly taken.

If the area is small and isolated, one of the most common methods of repair is a bituminous patch. This may consist of a mixture of stone and bitumen prepared on the site, but better results can be obtained by using a cold bituminous mixture prepared in a large plant under more precise methods of preparation. A bituminous mixture is not only suitable for repairing surface defects but may be used temporarily for the repair of an area which has completely broken down and disintegrated, or for the temporary repair of a cut made for access to a public utility structure.

The use of bituminous materials on concrete pavements is, however, open to the objection that the patch presents an entirely different appearance from the rest of the pavement and is, therefore, somewhat disfiguring. For that reason bituminous materials should be considered as temporary expedients, to be used only until such time as permanent repairs may be made with materials similar to the balance of the pavement.

Whether the defect be a comparatively shallow one, a full-depth defect or a utility opening, the first step in the preparation of the permanent repair is to remove all loose and unsound material. The edges of the opening should be carefully squared and trimmed to a neat line. No attempt should, however, be made in the case of a full-depth patch to produce a smooth uniform surface throughout the entire depth of the pavement. The lower part should be left rough to increase the bond and, if the pavement is reinforced, sufficient of the old reinforcement must be exposed to provide for proper lapping and tying in of the new reinforcement, which should be similar to the old reinforcement. In the case of a utility opening the area of concrete removed should be at least 6 in. (and preferably 1 ft.) greater all around than the area excavated, to provide as firm as possible a foundation for the edges of the patch. The edges of the old pavement and, in the case of a surface defect, the surface of the remaining concrete should be thoroughly cleaned and well dampened, so that there will not be an abnormal absorption of water from the new material when placed. Immediately before placing the new pavement mixture, all exposed surfaces should be thoroughly painted with a thin neat-cement grout. The area to be repaired is now ready for placing the concrete.

There are on the market numerous materials which are recommended as admixtures. Many of these are of extremely doubtful value, and many of them have as their principal constituent the familiar and cheap calcium chloride. Either standard portland cement or high-early-strength portland cement may be used. Our experience has been such as to make us skeptical of the value of any cement other than a true portland cement. Generally speaking, unless high early strength is required, it is recommended in making repairs to large areas that the same proportions and sizes of aggregates be used as were used in the original pavement, if these can be determined.

In making repairs to small openings the cement ratio should, however, be somewhat increased. If it is not possible to make an accurate determination of the exact proportions of the mixture, some such arbitrary proportioning as 1 part cement to 1½ parts sand and 2 parts coarse aggregate will probably give fairly satisfactory results. The size of the coarse aggregate should, of course, vary with the character of the opening to be repaired. Full-depth patches will permit the use of standard sizes of coarse aggregate: in making shallow surface patches, however, the size of the coarse aggregate should be proportioned to the depth of the patch to be made.

Regardless of the proportions of the mixture and the size of the aggregates, the water-cement ratio should be kept so low as to produce an extremely dry mixture. Inclusive of any admixtures and moisture content in the aggregates, the total water-cement ratio will probably never exceed 4 gal. per bag of cement and will generally be found to be materially below this figure. The mixture should, in all cases, be prepared in a power mixer rather than by hand mixing. Where no admixture is used the mixing time should be from 2¾ to 5 minutes. Where admixtures are used care must be taken not to increase the mixing time to such a point that a flash set will take place in the mixer or before a proper opportunity is provided to place the material.

The concrete should be placed in layers varying from 2 to 4 in. thick, depending upon the presence or absence of an admixture, and must be thoroughly tamped into place. The final course of material should be very thoroughly tamped, so as to bring sufficient mortar to the surface to make it workable, and then struck off slightly higher than the surface of the surrounding pavement. The patch should then be allowed to stand until the initial set has taken place. This will, under ordinary temperature conditions, occur in from 10 to 20 min. after the final tamping and striking off of the surface, and may generally be recognized by the sudden disappearance of the slight water film which generally is found upon the surface of a well tamped mixture. At the time of the initial set the patch should again be thoroughly tamped, struck off to the proper elevation and finished in accordance with the usual procedure. This re-working of the patch after the initial set has taken place is an extremely important factor in insuring a bond between the old pavement and the new material in the patch. Accepted curing methods must be used.

All of the above procedure is based upon the use of first-class new materials, skillful workmanship and proper tools and equipment. The re-use, as coarse aggregate, of old disintegrated concrete is an unsound and improper procedure and should in no case be permitted.

Mudjacking settled slabs

THERE are two main classes of settlements to be dealt with. The first class usually involves merely one end of a slab at a transverse joint and is, it is believed, the result of extremely heavy axle loads, probably combined with some sub-grade instability. It also may result from an insufficiency of dowels between the two slabs. It will sometimes be found to exist on both ends of a slab, although it is more common on the end of a slab approached by traffic. These settlements frequently are less than ½ in. in depth but, if not given attention, show a tendency to progress and cause cracking and other serious deterioration in the slab.

The second class of settlement involves material subsidence in the subgrade and may involve only a short portion of a slab, or a larger area of the entire road. It is not infrequently accompanied by a side-slipping of the slabs.

Both classes of settlements have been very successfully dealt with by mudjacking. In this process 2¾ in. holes are drilled through the slab with an ordinary air jackhammer. No arbitrary rule can be laid down for the location and spacing of these holes other than that they should be so located and spaced as to permit injection of the necessary jacking material uniformly throughout the area to be raised.

The material to be pumped under the slab should be a finely screened loam. The equipment with which we are familiar is so designed that any appreciable sand content in the loam entirely excludes the possibility of its use. Before feeding the loam into the mudjack there is roughly mixed with it a minimum of two bags of portland cement

to the cubic yard of topsoil. If more rapid drying and greater stability are desired, the cement content may be increased. The maximum used in our experience is six bags to a cubic yard.

The mud-jack is a continuous pugmill type mixer which further combines the cement with the topsoil and combines water with it so as to form a plastic and fatty mixture. From the mixer it is pumped through a hose into the holes already drilled in the pavement. The consistency of the material must be varied; a thin consistency must be used generally in starting the jacking operation and for comparatively small raises, while stiffer consistencies can be used in the later part of an operation and should be used in bringing up heavy settlements.

In jacking up a concrete slab by this process it should be borne in mind that the operations must not be confined to a single drill hole, but must be distributed uniformly over all the holes in a slab, so as to raise the whole slab gradually to its proper position. Unless this important principle is kept in mind there is strong probability that an uneven surface will be produced and the slab will be cracked or otherwise damaged.

It is impossible to set forth in detail any hard and fast rules for the guidance of either the supervisory or actual labor forces on such operations, since many different factors are encountered, and experience in the handling of the work is of far more value than any rules or regulations. The main factor is close observation of the movement of a slab and care in carrying out the work. The size of the crew required to carry out mud-jacking operations will vary considerably with the conditions, but the minimum will generally be twelve men.

Surface treatment

WHERE scaling or peeling of the surface has progressed to the point where a large percentage of the surface is involved, it not infrequently becomes necessary to take some steps for the protection of the remaining surface. There are at least four procedures possible: (1) resurfacing with a thin concrete slab; (2) resurfacing with a bituminous surface, such as bituminous concrete or sheet asphalt; (3) resurfacing with a bituminous retread mixed-in-place surface; and (4) a light surface treatment. The first three of these plans would probably be generally considered as involve the abandonment of the existing pavement as a concrete pavement and its transformation into a concrete base. They should not, therefore, be considered in this discussion.

The light surface treatment, however, should properly be considered as a maintenance operation. Successful and economical results have been obtained from use of hot tar showing a float test of from 60 to 150 at 32 deg. C., and from a quick-breaking asphalt emulsion. About ¼ gal. per sq.yd. of either of these materials is used and covered with from 25 to 35 lb. of ⅜-in. crushed stone chips. The resulting carpet coat will have a thickness of about ¼ in. It is entirely possible that the first treatment applied will show more or less peeling out in spots under traffic, particularly following continued rainstorms. Such small defects are, however, easily repaired by painting the surface with similar bitumen and reapplying a coating of stone chips. Such treatments will, under normal conditions, probably have to be renewed about every three years.

Brick Road Craftsmanship

Refitting base, cushion and brick course calls for a nicety of handwork provided only by trained repairmen

By G. M. Anderson

Assistan Director, Ohio Department of Highways, Columbus, Ohio

THE MAJORITY of failures in brick pavements may be traced directly to weaknesses in the foundation or supporting elements, which are the cushion course, the rigid base course and the underlying earth subgrade. Disintegration of the brick themselves occurs to a certain degree, but it accounts for only a small percentage of the conditions developing in brick pavements which involve maintenance. These conditions may be apparent as a complete pavement settlement, as wide surface cracks, as a crumbling or disintegration of the brick units, as pavement upheavals or blow-ups, as frost heaving, as surface drainage of underground water or in a number of other ways. To repair the condition requires first that it be analyzed to learn the cause of the failure.

Failure analysis should be conducted methodically from the top down, as follows:

1. The joints should be inspected to learn if they have been properly filled, and with the proper material.

2. The brick should be inspected to learn if they are sound and may be used for replacements.

3. The condition of the cushion material should be noted to learn if there has been any escape of the cushion aggregate which would account for brick settlement, and, if such is the case, why.

4. The base should be inspected to learn if cracks have developed and why; or if there has been disintegration of the base structure and why.

5. The subgrade should be inspected most carefully to learn if it is composed of an unstable material; or if it becomes seasonally unstable; or if the underground drainage is inadequate or ineffective; or if there is some roadbed condition that should be corrected.

In most cases it is not difficult to diagnose the cause of failure. The correction of the condition then must proceed in reverse order to the analysis.

In nine cases out of ten subgrade troubles are due to water. This being the cause, then drainage is the cure. Engineers all recognize the necessity for adequate drainage—and then too often refuse to practice it. It is unnecessary to elaborate on drainage other than to emphasize that there must be two systems in any highway roadbed; one to carry off surface or "quick water"; and even more important, one to intercept and carry off subsurface or underground water. Too often, surface water ditches are expected to serve both purposes. Underground drainage in maintenance may imply tile or pipe drains; or subgrade composition having inherent drainage properties; or an intercepting layer of porous material below the frost line; or a combination of these methods.

It seems difficult to associate the average maintenance crew's work with soils laboratory research, yet the coordination and cooperation of these two activities is the only answer to economical and certain accomplishment in maintenance, where subgrade faults are involved. Maintenance crews are able to perform

the mechanical tasks for producing subgrade stability, but it requires laboratory knowledge and equipment to direct their efforts intelligently to the end that the desired results may be secured. Subgrade sampling, analysis and recommended treatment, where failures have occurred due to subgrade conditions, should become routine procedure of the soils laboratory and the highway maintenance organization.

In present practice, rigid bases for brick surface courses are designed to accommodate normal stresses within the limits of present knowledge. When base failures occur there is implied abnormal stress from one cause or another. Such a condition must be recognized and provided for in the repair of the failure. The actual operation of repair requires that the entire failed portion be removed, the corners and adjacent base faces squared, and the base restored slightly thicker than the original. The replacement should underpin the adjacent existing base. The surface should be carefully brought up to the proper grade and cross section, and with the proper installation of transverse and longitudinal joints carefully constructed in accordance with standard practice. Crevices which may permit the escape of the cushion material should be avoided where possible, and where such crevices are necessary they should be carefully filled and sealed with heavy bituminous material or mastic.

The use of black base (hot mix if convenient) may be practicable if the size of the patch is sufficient to allow for proper rolling and proper finishing, or if other suitable methods for compaction are available. For this purpose arbitrarily-proportioned field-produced cold-patch mixtures should not be confused with stable bituminous-concrete or penetration-macadam bases using proper bituminous cements.

If the failure proves to be but a minor settlement and the base is found to be in good condition, it may be satisfactory to build up the base carefully with lean bituminous cold patch, but this practice should not be adopted as standard in repairing first-class brick pavements; where this type of repair is employed, plant-mixed bituminous concretes, using semi-solid cements, should be secured if available.

Stable cushion material

THE cushion is a very important part of a brick pavement. Its composition should be such as to minimize its susceptibility to movement. Granulated slag or slag screenings make excellent cushion material where available. Prepared limestone sand is not nearly so susceptible to movement as are most natural sands, due to the angularity of the particles as compared with the roundness of most natural sand particles. Sand or stone screenings treated with a small percentage of bituminous cement, or lean, naturally-impregnated asphaltic sands or limestone screenings, make excellent cushion materials.

When cracks develop in the base the cushion material, if unstable, will sift away into the cracks, allowing the brick to settle and break the bond between the joint filler and the brick, which in turn allows entrance of water at the surface, further distortion of the sand cushion and disintegration of the filler material. The less stable the cushion material, the more rapid and extensive will be the escape of the aggregate particles through the openings underneath. It has also been shown, in recent studies, that cushion material may escape through open joints in the brick surface course, due to the suction of pneumatic tires. This can occur only if the cushion material is such that little resistance to displacement exists. It then follows that not only must cracks in the base be carefully filled, but also those in the brick surfacing course must be closed. It also becomes more apparent that maximum stability in the cushion material is an important consideration. Extensive research and tests seem to indicate that a solution to this problem is not far distant.

In spreading the cushion material, templets cut to the proper cross section should be used to strike off the course to proper depth. Allowance must be made for the compaction of the material, or its squeezing up into the brick joints. Sufficient depth of cushion should be provided along curbs to allow the brick surface course, after compaction, to extend ¼ to ½ in. above the curb. It is better to have the surface course elevated above the curb the maximum amount than to have it depressed even a small amount below the curb. It seems to be a weakness of maintenance crews to allow the latter condition to occur at curbs and particularly at catch-basin gratings, manhole covers and similar fixtures.

Where half widths of pavements are repaired to maintain traffic, the cushion material is likely to escape slightly from the already repaired half width, when laying the adjoining half width. Allowance for this condition should be made by not filling the joints of the completed half, within 18 in. of the longitudinal joint. This will permit taking up the brick in this space and adjusting the cushion to conform with the half being laid. Failure to observe this practice is often discerned in a slight settlement at the longitudinal joint after traffic has been allowed to travel the completed section. Too much care cannot be exercised in selecting, preparing and laying the cushion course.

Bricklaying a bungled operation

Relaying or replacement of the brick is a simple problem, yet it is the operation that is most commonly bungled by maintenance crews. The reason for most bad or bumpy patches is that the maintenance foreman just doesn't want to take up any brick once they have been laid. There is just one solution to this problem—the same crew should be made to do the job over again until it is right. To our knowledge a crew has been made to take up a replacement three times before it was finally accepted. Today this same crew is one of the most efficient brick-repair crews in the state. The foreman and each member of the crew is just as proud of a neat repair job as their superintendent, and this lesson in neatness is reflected in other tasks this crew is called upon to perform. The cost of the lesson is more than justified.

Tools and methods

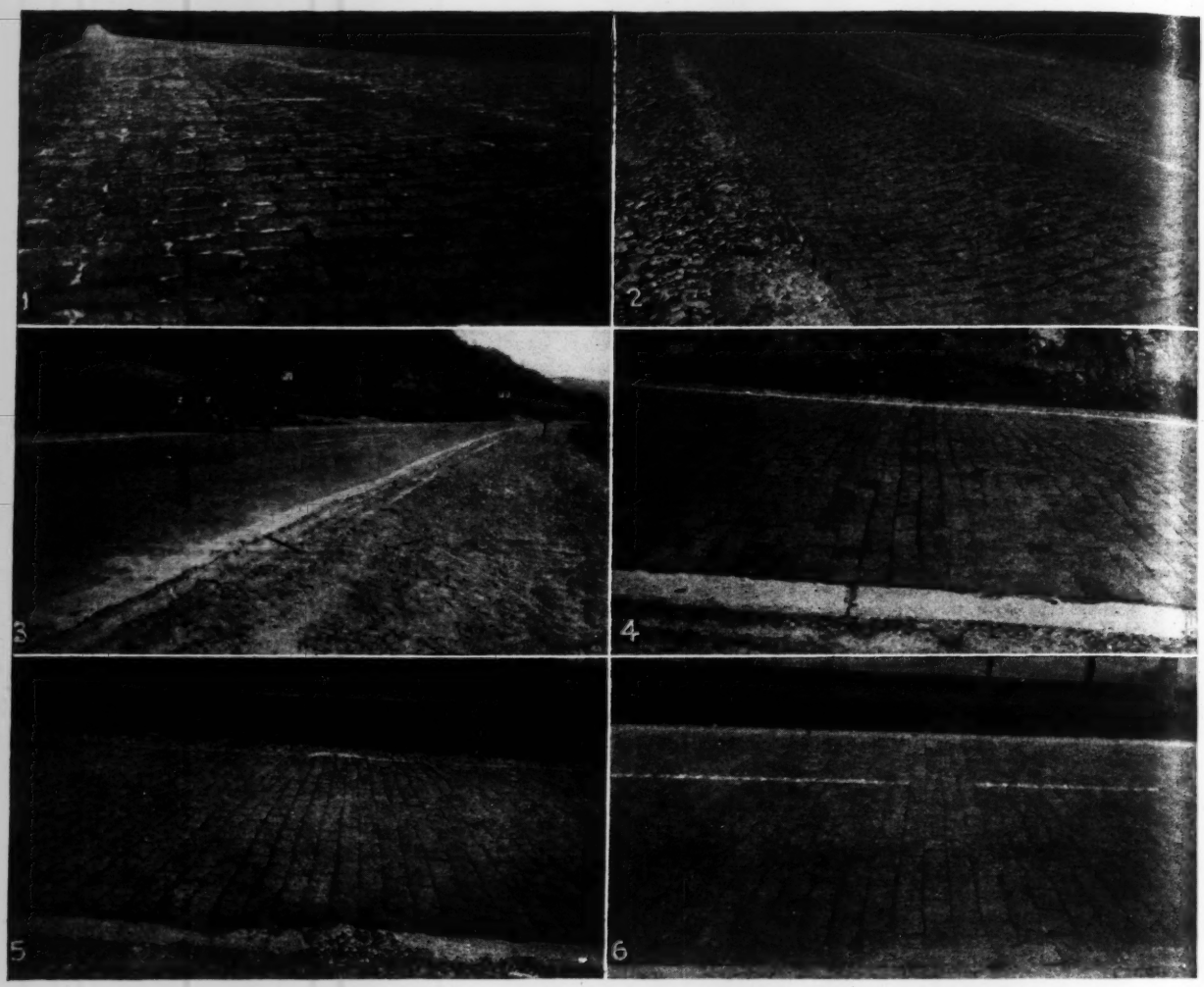
The straightedge is perhaps the most important tool to be used in relaying brick, and it should be used often and carefully. Finished grade stakes, chalk lines and finished cross-section templets should also be used to check the finished surface. If high or low spots develop after compaction (and it is not a reflection on the workmen if they do) the brick need only be removed and the cushion adjusted.

If the old brick are to be salvaged they should be thoroughly cleaned of the filler material. This seems like a tedious task, but a crew can salvage brick, with respect to cleaning, for one-seventh the cost of new brick. The old brick should never be discarded for use if they are otherwise sound and serviceable.

Breaking the joints of adjacent courses and keeping the courses straight are important. If the repair section does not "end up" exactly right with the old surface, many times the individual courses may be spread or adjusted slightly with the flat end of a brick hammer so that each individual transverse joint will be widened only a trifle, yet the patch will fit up nicely with the old surface. This adjustment, however, must be carried out over a sufficient area so that several courses will share in the distribution. Too often this is not done, and the joint between the patch and the old surface is as much as ½ in. wide and is conspicuous and unsightly.

Sometimes the "end up" space is too great to be adjusted in the above manner. This condition may be easily corrected by laying a header course, in which the brick are laid at right angles to the remaining courses. In some cases the brick may have to be shortened to fit, but the irregularity of the joints destroy the unsightly appearance resulting from a continuous wide joint between courses.

Sometimes only half or a smaller section of surface must be repaired, and it becomes difficult properly to tie in or dovetail the replacement with the old surface at the centerline or other longitudinal joint, and at the same time maintain the uniformity of the joints between courses. This is particularly the case when the replacement brick units are not the same size as those in the surface



TYPES OF BRICK PAVEMENT FAILURES SHOWING METHODS OF MAKING REPAIRS

FAILURE due to escape of cushion material through longitudinal crack in base; note flexibility of brick units. (1)

BRICK WEARING surface on concrete base with sand cushion. Failure caused by inadequate underground drainage. Note soundness and flexibility of brick units and disintegrated curb. (2)

A SECTION of new pavement. Note the settlement of the right hand curb in the center foreground. This failure will require raising or replacement of the base and wearing course. (3)

ESCAPE OF SAND cushion at a transverse joint. Note the width of the crack in the curb and the extent of the settlement of the surface course as indicated by the open joints. (4)

FAILURE due to expansion in the base. Note the crushing of the curb and the flexibility of the surface course. (5)

A NEAT REPLACEMENT OF a joint settlement, due to escape of the sand cushion. Note the limits of the replacement by the broken center stripe. (6)

being repaired. A simple solution of this problem is to lay a single header course along the longitudinal joint, and then butt the replacement course against the header, just as would occur when butting against a curb. Both replacement and old surface, of course, will have to be "batted" to fill in the half-brick voids. When this header course is along the centerline, the centerline marking usually hides it, although it is not in itself unsightly.

After the brick have been laid they should be rolled or tamped thoroughly to imbed them in the cushion course. If a roller is not available—and many times this equipment is not justified in making widely separated and individually small-sized patches—tamping is very satisfactory if properly done. A plank 10 to 12 in. wide, 2 to 3 in. thick and 8 to 10 ft. long should be used to distribute the compaction. The tamp should be made of wood and fairly heavy. An 8x8-in. post 18 in. long, with handles on the sides, makes a satisfactory tamp. The plank should be laid parallel to the centerline and tamping should progress from the curb to the center, each successive move of the plank, transversely and longitudinally, overlapping slightly its previous position. Direct contact between the tamp and the brick should be prohibited except in isolated cases.

After compaction has been completed the section should be straightedged and carefully checked, and high or low places removed and readjusted. Broken or otherwise unsuitable brick should be culled, replacements made and the section again compacted. In culling brick, many times slightly-spalled units may be turned over with the good side up. Also, such brick may be used for batting.

Watertight joints vital

Periodic filling of joints should be a regular routine operation, as unfilled joints permit excessive inflow of moisture. It is especially important that joints should be kept well sealed on brick wearing surfaces over bridges, to guard against saturation of the cushion and subsequent disintegration of the concrete superstructure. Proper weep holes for the cushion course should be provided in structures of this kind. Also, as previously stated, joints should be kept well filled to prevent the escape of cushion material due to tire suction.

In filling joints, the same kind of filler used in the original construction should

be used if possible. Many times it is found that the old filler no longer has life, yet has bulk enough to resist the entrance of filler material of standard consistency. Asphalt emulsion seems to work best in this condition, due to its fluid and penetrative properties with resultant heavy consistency and slight susceptibility to weather changes. Moreover, where the difficulty of pouring the joints insures that some filler material will adhere to the surface, the nature of the emulsion and the fact that most of the excess may be broomed into the joints ensures that only a very thin film of bituminous material will be left on the surface, which is soon worn away by traffic. As much sand as possible should be broomed into the joints before application of the emulsion so as to "hole up" the emulsion in the joint until it becomes broken and set. After thorough brooming any excess should be covered lightly with sand.

Where standard asphalt fillers are used, the whitewash method of application is very satisfactory, as it eliminates the possibility of an excess of bituminous material on the surface, with subsequent slipperiness. This method consists of spraying a thin application of a lean limewater, calcium chloride, or other suitable solution on the newly laid brick just prior to the application of the filler. An ordinary fruit-tree sprayer may be used for this purpose, or brooming of the lime or other solution may be satisfactory. The lime or other solution produces an insulating film on the surface which prevents the adhesion of the filler. Immediately after the surface has been sprayed with the solution, the filler is poured onto the surface from buckets or other suitable containers. It is important that the filler be heated to the proper temperature when using this method to insure complete penetration into the joints. As soon as the filler has congealed, the excess is removed with a tool (an ordinary garden hoe straightened out), and the removed material is replaced in the heating kettle to be used over again. This method does not add to the cost, because the saving in filler compensates for the extra manipulation required, and the full advantage of the antiskid wirecut surface of the brick is presented to traffic.

When an excess of bituminous material exists on an old surface, defeating the non-skid characteristics of the brick, it may be removed at small cost by placing a coating of sawdust over the surface, saturating the sawdust with kerosene, then setting fire to the mixture. The heat softens the filler so that it may be scraped off with straightened-out hoes. This operation must be carefully performed to avoid overheating and cracking the brick.

Curb repairs troublesome

Disintegration and weathering of concrete curbs presents a maintenance problem that is not easy of solution. Unquestionably most of these failures are due to faulty construction. Unless the curb has become so badly damaged that complete replacement becomes necessary, the simplest treatment consists of bituminous cold patching and point patching. This type of treatment is unsightly at best, yet complete curb replacement is not only tedious and slow but also presents the problem of joining the replacement with the base. When repairs of this kind are necessary, high-early-strength cement should be used to accelerate the curing of the concrete.

Maintaining Macadam Roads

Bituminous macadam design and structure determine methods as well as amount of maintenance

By Bernard E. Gray

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BEFORE PROCEEDING with the maintenance in detail, it will be well to set forth clearly what is intended by the term bituminous macadam, because it has become rather broad in its application, and may mean one thing in New England and quite another in the South or West. Strictly speaking, bituminous macadam may be any surface course which is composed of coarse graded aggregate bonded with a bituminous cement. It may be mixed in a plant or on the road and then finished as a mixture, or it may be constructed by penetrating the previously spread aggregate with the bituminous material in successive applications.

Some states call both hot and cold mixes bitiuminous macadam but distinguish the penetration method from the mixing method in just such terms. In Oregon, a layer method of constructing bituminous macadam is followed, locally termed "multiple lift," which produces excellent surfaces. In some mid-Atlantic states, a type known as modified bituminous, or in the vernacular "puddle macadam," is widely employed, particularly in using sandstone for aggregate. All of these are developments of the original macadam design, whereby bituminous cement has been substituted in whole or in part as the binding agent in place of the dust and screenings originally used. In this paper only those types in which the bituminous binder is applied by the penetration method will be discussed.

The maintenance procedure on these types is so dependent upon the materials used and the conditions under which the surface was placed, that a brief description of the principles underlying design will be the best way to arrive at an understanding of the problem. An engineer having available only a very soft stone for aggregate is apt to be skeptical when he reads that no maintenance is required upon a bituminous macadam before seven to ten years, and conversely the builder who has developed a sound technique using tough, hard, trap rocks, is apt to be a little scornful when he reads that the other engineer is applying a surface treatment every three or four years. Prof. John S. Crandell, discussing the question, in one of his clever papers several years ago, said:—"There are many states where the macadam road is looked upon with distrust. This is so because these states have never built macadam. What is often termed macadam is nothing short of a libel on the name. Oftentimes it is built of poor stone, thinly spread, poorly rolled, improperly bonded, and no maintenance. What can be expected of such a road?" The construction and maintenance of any road-type requires brains and experience, and the amount and kind of maintenance required on penetration bituminous macadam will be small or great according to the ability of the engineers in charge.

The bituminous or so-called penetration macadam surface was officially recognized as a pavement in 1912 by the Association for Standardized Paving Specifications. As first constructed it

called for a hot bituminous cement as binder, and its use spread from the North Atlantic States to other parts of the country without much regard to the changing character of aggregates available. Even where good aggregates were had, it was often difficult to enforce the seemingly insignificant details of clean stone, uniform sized stone and uniform application of binder, with the result that many surfaces developed uneven conditions, even though they never seemed to wear out. Fortunately these poor examples have been partially resurfaced, or rebuilt.

These variations in quality of aggregate and the consequent need for modification in technique are now quite generally recognized, and have led to the establishment of the following general procedure:

Group (a) Hard, tough aggregate with large voids, and high interlocking characteristics, penetration with hot asphalt cement, sealed with hot asphalt cement.

Group (b) As an alternate to (a) especially if the aggregate while hard, yet tends to fracture under rolling so that voids become smaller, penetration with emulsified asphalt or heavy rapid curing cutback asphalt, sealed with some material.

Group (c) Softer aggregate which crushes under rolling so that practically no voids remain, penetration with medium curing cutback asphalt, sealed with a rapid curing asphalt (hot or cold) and covered with a hard aggregate.

Included in the first group (a) is the well known bituminous macadam type of New England, which in the words of McAvoy of Massachusetts "ranks the equal of any pavement type in load resistance, durability and traffic service generally." It does so because of scrupulous attention to construction details; the establishment of thorough drainage and the availability of excellent stone. The old rule for the penetration wearing course was that the thickness of the course, the top size of the stone and the quantity of the asphalt should be the same. It applies within limits if the stone is sufficiently hard and tough to resist crushing under the roller; it does *not* apply with aggregate which crushes under the roller.

Early penetration surfaces were usually 3 in. compacted depth. Under heavy traffic, variations in void sizes were apt to cause noticeable unevenness in penetration, and sometimes led to lateral displacement, so that the trend in recent years has been to obtain a compacted depth of 2½ in., using a top size stone of 2½ in., and from 2¼ to 2½ gal. of hot asphalt per square yard. With excellent quality stone it is desirable to have traffic wear come directly upon the coarse aggregate in which case the binder application should be about 2 gal. and the seal application about ⅜ gal. with a minimum amount of ¾-in. aggregate cover. For slightly softer stone it is better to increase the proportion of seal application and to cover with a greater quantity of aggregate so as to produce a somewhat denser surface texture. The first procedure would obtain for hard trap rock, the second for slightly softer traps, hard granites, hard limestones and hard slags.

It is of course difficult to differentiate sharply between an aggregate that is suitable for group (a) or group (b) procedure. It is evident however that the use of the lower-viscosity bituminous materials, is predicated upon the presence of the smaller voids which are found in finer-sized aggregates. Where there is any doubt as to type, it is always better to use the lighter products, because in the successive application of bituminous material and cover aggregate, variations in void size in the coarse aggregate are evened up to a uniform condition. With a hot cement it is absolutely essential that the voids be uniform and large, otherwise the heavy material will be held up in spots and will make bunches no matter how much rolling is done afterward.

Another item which may control selection of procedure, is the price range on local commercial aggregate. Very hard, tough rock tends to break into a relatively coarse one size range, and the production of stone chips and screenings is small. Hot penetration macadam requires a minimum of five sized aggregate. The crushing of softer aggregates tends to produce a substantial amount of particles between ¼ in. and 1¼ in., which are yet sharply angular and relatively free of dust. Aggregate of this character is well suited for group (b) procedure.

Group characteristics

In group (a) the strength of the surface is dependent upon high interlocking action between the coarse particles which are held that way thereafter, with the very thick films of hard cement. In group (b) the strength is dependent upon the successive wedging of smaller sized particles into the voids left after each previous application of aggregate and bituminous material, and which are held in place with the relatively thin films of a softer cement. This latter procedure requires from three to four applications of aggregate and bituminous material, and it is a mistake to attempt to achieve results with any less. Only enough aggregate should be spread after each application of bituminous material as will fill the voids, and all surplus should be removed before the next application. When care is taken in this respect a quite mosaic texture may be obtained except that it is of a finer grained structure than the hot penetration surface.

In group (c) are those aggregates which crush considerably under even light rolling, and which are impossible of use by the hot penetration method, or even with the heavy liquid products. Sandstone and sandy shales, the soft limestones and slags come in this category, and until the development of the modified procedure, were considered unsatisfactory for bituminous macadam. While specifications usually restrict the use of aggregate to a per cent of wear of 6 or below, quite satisfactory surfaces under medium traffic have been built with aggregate having a per cent of wear as much as 8 or 10 provided it was of granite or sandstone composition.

Large quantities of fine sized stone and screenings are produced in the preparation of group (c) aggregates, even though the coarser sizes are made somewhat larger to begin with than the harder aggregates. Instead of rolling the coarse aggregate to keep it firmly in place, only a light once-over rolling should be done, simply to obtain a proper cross section. The surface should then be covered with screenings in sufficient amount that at all times there is a quarter inch or more depth above the coarse particles. The rolling, brooming, and consolidation should thus be carried on so that the voids are completely filled and yet produce little or no crushing of aggregate. The surplus screenings should then be broomed off, exposing the coarse stone in a matrix of fine aggregate filler which has strength because of its density.

To preserve this condition a highly penetrating bituminous material is required, which will thereafter harden to a soft cement, and yet be pliable enough to recement any small cracks which develop under traffic. The top size aggregate may be as much as 3½ in., and will under one rolling accommodate itself to a 3 in. compacted thickness. The penetration application of bituminous material is all the surface will absorb, usually about 1 gal., with penetration of around 1½ in. The seal coat may be of hot or cold material, but as a rule the latter is preferable. Where the aggregate is very soft the cover should be brought in from another source, as it should sufficiently harden to resist abrasion.

Base—In the construction of foundations, that combination of base and sub-base should be selected which will give the lowest cost consistent with load distribution and drainage. In glacial areas where sandy gravel is available, a sub-base 4 to 12 in. depth according to sub-grade conditions should be placed, and with the base course held at a constant depth (compacted) of around 4½ in. For other areas it may be more economical to construct both base and sub-base of coarse aggregate, and of such depth as is required to distribute the load over the particular subgrade. Much unnecessary maintenance has been caused by failure to provide a proper sub-base. Even if it is only a blanket course of sand or screenings an inch or two thick, it should be placed as it provides a cut off barrier against the rise of water into the base and top course.

Drainage — Every highway engineer

should take a vow each day upon arising that he will make a greater effort to have the roads under his care properly drained. The way in which this all important item is overlooked both in construction and maintenance has added much unnecessary expense to the annual highway bill. The flow line of ditches or at least the ground water line should be well below the base in order that it shall develop its maximum strength. Frequent bleeders through the berms, sloping down grade, should be installed to insure base drainage where the shoulders are of impervious material or where the ditches for any reason cannot be lowered. Tile drains in heavy clay soils are practically useless and the coarse aggregate bleeders are much to be preferred.

Lateral support of surface—Bituminous macadam comes in the class of flexible surfaces, and its design is based upon the distribution of load at an angle of approximately 45 deg. It is evident therefore that if a wheel load is applied at the edge of the pavement, complete lateral support must be afforded by the shoulder, or else there may be failure. Practice in New England calls for building of berms prior to and even with the surface of each successive lift of subbase, base and surface, and their rolling and consolidation simultaneous with each layer. Care is taken to select quality material for berms, so that as completed, they are practically pavements themselves. In many instances the berm surface is given a light bituminous treatment which renders them waterproof, and insures shoulder stability at all seasons. It is a procedure that could be universally adopted to advantage.

Another method of providing support is to extend the sub-base and base course 1 ft. or more outside the wearing course, bringing the shoulder material over the base course to its edge. As traffic tends to hold the pavement this usually insures adequate load distribution without edge settlement.

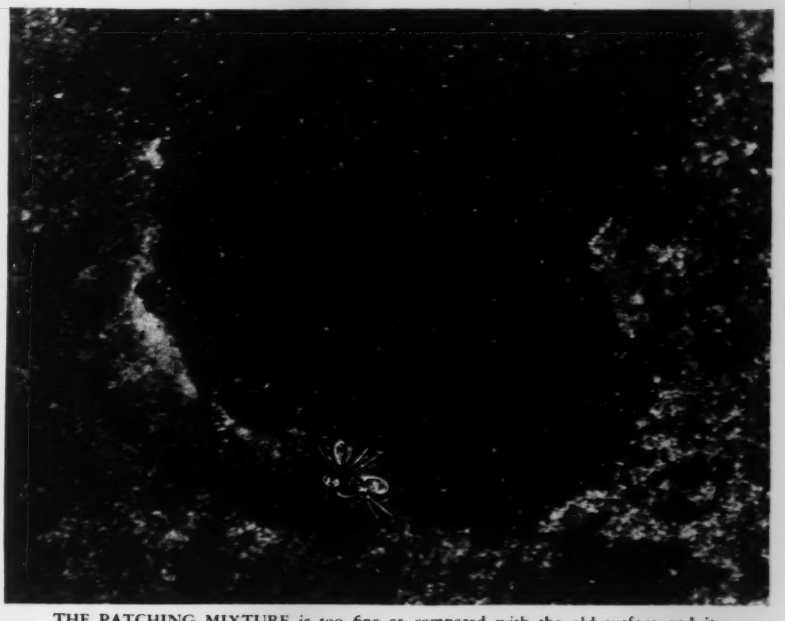
Still a third method, but higher in first cost, is to build a wider surface than required for two-lane traffic, but not wide enough for three lanes. Many 22 and 24 ft. width surfaces are built for the purpose of providing greater lateral distribution of traffic, and yet with ample margin so that the outside edge is rarely approached. There is no merit in the design of a thickened edge for macadam pavements, it being far more preferable to obtain a greater width with uniform depth of cross section.

Maintenance procedure

With these three distinct types of bituminous penetration macadam, having quite different surface compositions, and different capacities for traffic, there is some difference in maintenance procedure. It may appear that considerable space has been given over to a discussion of design, but where construction technique is based upon sound design principles, the need for maintenance is kept at a minimum if not in fact deferred for some years. Squire Fitch of New York several years ago made analysis of design and costs of the bituminous macadam roads in his state, which appeared in the proceedings of the Fifth Annual Asphalt Paving Conference. Very definitely certain critical limits were evident above which annual maintenance might be as much as $1,000, below which as little as $174, per mile per year.

Base Failures—Maintenance on macadam may be divided into two classes: one, modern type surfaces, the other, surfaces usually 15 years old or more. Modern surfaces built with group (a) aggregates, hot penetration type, should not require any surface maintenance for at least seven years, except for an occasional base failure, or a small area with too much or too little bituminous material. Base failures are the same regardless of surface type, and there is only one remedy—take them out. Usually the failure is caused by water, often dammed back by a rock ledge or impervious soil layer in the subgrade or held by inadequate side drainage. Whatever the cause it should be searched out

ENTIRELY WRONG PATCHING, aggregate size much too large for depth of patch.



THE PATCHING MIXTURE is too fine as compared with the old surface and it will break out.

and remedied before placing a new base course. It is always a good rule to place a new bleeder drain through each shoulder, wherever the repaired area is on a grade, so that underdrainage will be provided.

In replacing base and wearing course it is often difficult to consolidate with a roller, particularly in small areas at the junction with the old surface. For such areas compaction may be obtained with an air tamper or with an offset tamper. The first is the usual pneumatic tamper operated from a portable air compressor and widely available. The second is of comparatively recent origin, the tamper being mounted on an offset arm usually attached to a tractor and operated from a power take-off much like a pile driver. Originally developed for consolidating base course widening using bituminous mixtures where rolling was impractical, it is equally well suited for all sorts of repair work in small areas. Whatever the means employed, the greatest care should be taken to obtain substantially the same density as that in the adjoining pavement in order to prevent subsequent settlement. Sometimes a temporary surface is placed over the new base, to be used until the base becomes finally compacted under traffic, when it is removed and the permanent resurfacing is placed.

Surface Defects—If proper care is taken in the placing of aggragate and the application of bituminous material, the surface will be uniform in character. Occasionally however there will be a dense pocket in the aggregate, or one or more large stones, or dirt which for some reason is overlooked, and a fat spot in the surface will result. If the excess is not great, (less than $\frac{1}{8}$ in. deep) it is better to leave it alone, especially if it is only a small area, for except for appearance it will do no harm. Under no circumstances should it be covered with aggregate, as a bump will occur. If there is a large excess, the best procedure is to heat with a small surface heater, cover with sand and then shovel off the sand-asphalt mulch. Care should be taken not to burn the surrounding areas nor to remove all the asphalt from the area affected.

Occasionally in the application of the bituminous material, a spray nozzle will become clogged, sometimes only partially and not be noticeable, and later under traffic this will show up as a lean streak. This seldom occurs with the group (b) aggregates because the number of applications of bituminous material is sufficient to overlap and prevent it, but it occasionally occurs with group (a) and group (c). Unless water is getting through the surface it is best left alone until the surface is retreated. If necessary for waterproofing, a light paint patch should be applied using cutback or emulsified asphalt and fine aggregate cover. As the voids are small, use of hot patch should be avoided, and with care in limiting amount of liquid binder and aggregate a skin patch can be placed that in a short while will become unnoticeable under traffic.

Patching—Probably no single item so shows the skill of the maintenance engineer as patching. A good patch should in a very short time become unnoticeable under traffic, which means that the patch must be of a composition similar to the remainder of the road. The rather wide practice of using the same kind of cold patch for any and all repairs without regard to the surface type is to be deplored. For one thing it is unsightly, for another and more important reason, the patching mixture while suitable for one location, may be harder or softer than the adjacent pavement in another, which sets up a differential wear leading to rough surfaces and in some instances to a ring pothole completely around the patch.

If the broken pavement is composed of a certain kind of aggregate the patch should be made from the same aggregate and of as nearly the same size as practicable from a manipulation standpoint. In group (a) except for very small patches the repair should be made by the hot penetration method, in group (b) with the smaller aggregates and liquid bituminous materials, and group (c) with the same soft aggregates and medium curing binders. It is absurd to patch a stone pavement having a per cent of wear of 3 with a patch mixture composed of particles with a per cent of wear of 6. The patch is sure to move under traffic. Likewise a soft aggregate surface patched with a hard aggregate mixture will develop high bumps in very short order. There is no useful end attained by making the bituminous patch deeper that the adjacent bituminous surface, for the same reason of uneven resistance to traffic.

Where both base and wearing course are replaced, the top course should be cut back from several inches to a foot beyond the old undisturbed base, so that when the repair is completed the jointings of the base and wearing course will be staggered.

The foregoing comments on patching apply to permanent repairs, but often temporary repairs are required because of weather conditions or lack of suitable materials and equipment. For this purpose there is nothing better than a dense graded aggregate mix made with sandy gravel, or stone and screenings, to which has been added a medium curing cutback asphalt. Such mixtures can be stockpiled in advance, are more easily manipulated in cold weather, are quite stable in the patch, yet can be removed readily in the warm weather when the final repair is made.

Retreatment—The principal item of maintenance for all macadam types is periodic surface treatment. The interval to a certain extent is governed by the traffic (amount and kind), and the character of the stone. Very hard trap is practically unaffected by traffic, except over a long time, being like stone block in that respect. With a sound base under it, the surface remains unimpaired for years, and the cement films are so thick as to be relatively unaffected by light, and hardening is therefore slow. Modern traffic however has changed in its reaction on a pavement. It now tends to tear up a surface instead of annealing it, and over a period of time, this tearing action pulls out the small particles in the voids and the pavement appears porous. In group (a) this time for retreatment may be from seven to fifteen years after construction, but there is no object gained in deferring treatment until the latter date even if the pavement would take it. It is much better to make a light treatment at the first evidence of a porous surface, and prevent any possible deterioration in the base from entry of surface water.

Often treatment is deferred for fear of losing the coarse open surface texture, but this may be easily preserved by cutting the rate of application to less than $\frac{3}{10}$ gal. per sq.yd., using cutback or emulsified asphalt covered with a fine aggregate all of which passes $\frac{1}{2}$ in. screen. The new film is so thin that the outline of the coarse stone will be retained, but the voids between will be sealed against water.

For the finer textured surfaces similar light treatments are recommended. The interval between treatments will be shorter, and with the very soft aggregates in group (c) may be as often as once every three years. In all cases the rate of application should be held to the minimum that will maintain the original thickness and waterproof condition. There is no advantage in making a thicker mat cover except where additional strength is required, and which involves resurfacing. So long as the base is adequate, retreatment should be only for waterproofing and wear replacement.

Repair of Old Surfaces—Many old macadams have been either resurfaced or retreated until they are stable, but many others are still very rough, and in addition have a high crown that reduces the effective use of the full road width. The practice of surface treating such roads without rectifying the uneven condition and reducing crown is hardly good maintenance procedure. By increasing the weight of treatment to as little as 50 lb. per sq.yd. of new coarse aggregate a marked improvement may be made.

Patching, base repair, and drainage correction is of course the same as outlined for modern pavement types and should be carefully checked before surface treatment. After sweeping the old surface, a light tack coat of the bituminous material should be applied at the rate of from one to $\frac{3}{10}$ gal. per sq.yd. and then immediately covered with about 40 lb. of aggregate spread at a

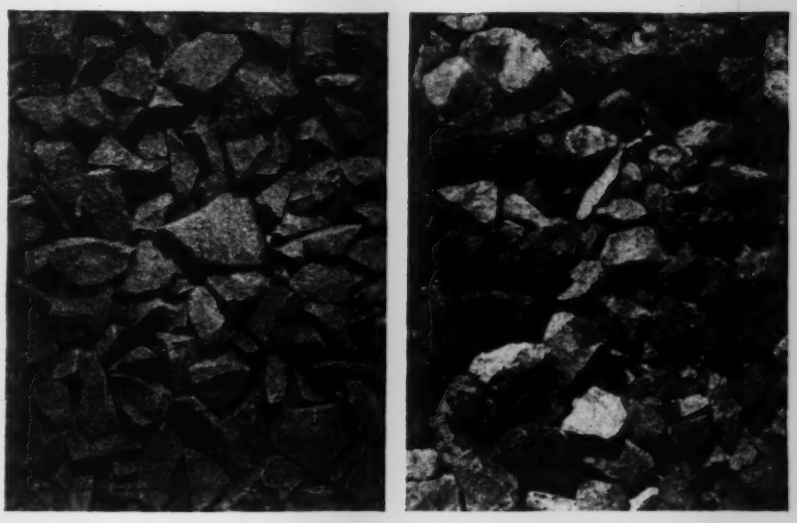
uniform rate per square yard. The second application of bituminous material is then made at the rate of about $\frac{1}{10}$ gal. per sq.yd., followed by a multiple blade drag having a rear strike-off screed. After one or two passes the aggregate and asphalt become thoroughly mixed, and the screed may be set to spread the mixture to a revised crown and profile. It is very important that the stone be spread at a uniform rate per square yard, so that with the binder applied also at a uniform rate, a constant mixture ratio will be obtained. Even with the variable depth at which the mixture then is spread, the alternate fat and lean spots which occur on an uneven surface under the conventional method of treatment are prevented. After a final seal coat of about $\frac{1}{10}$ to $\frac{2}{10}$ gal., covered with fine aggregate and thoroughly rolled, the surface texture resembles a uniform plant-mix. With a few treatments of this character the old roughness of the pavement will entirely disappear.

Equipment—The equipment required for routine or patrol maintenance is quite simple. Ordinary small tools include brooms and hard tampers, a small heating kettle fired by oil burners, (50-100 gal. size is sufficient) a truck to haul aggregates, pouring pots, wheel barrows, etc. There are several small kettle units now available which have attachments for pressure spray of bituminous materials, thus permitting the use of any viscosity product.

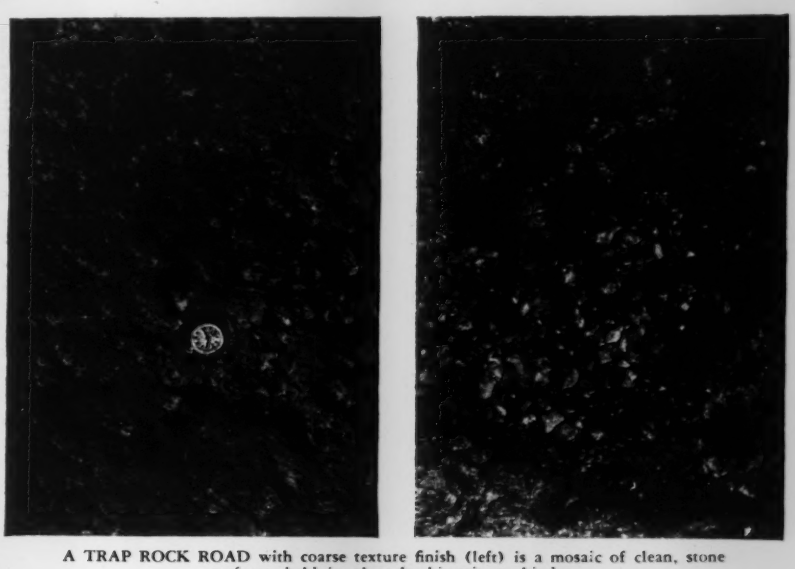
The major repairs each spring should be done under gang maintenance if possible, able to complete the entire range of repairs in one passage of the crew. Equipment required will consist of a ten-ton three-wheel roller equipped with pressure scarifier, a pressure tamper (previously described), a pressure distributor equipped with a manual spray nozzle, a small surface heater, trucks for aggregate, small tools, etc. The work should be laid out so that the advance group removes defective areas and corrects drainage, the second group replaces base stone and drainage bleeders, and the rear group consolidates the base, and completes all top course repairs.

Surface treatment operations require a rotary power broom, a modern-type distributor, a modern-type mechanical aggregate spreader, three-wheel rollers (principally of ten-ton size), multiple blade drags (for heavy treatments), trucks, small tools, etc.

Labor—Repair gangs are usually few in number, but they should be skilled men of considerable experience. Maintenance is more an art than a science and it pays to hold capable men. A gang of ten men will cover several miles a day in the spring repair, unless unusual earth work is encountered.



TRAP ROCK of uniform size (left), with sharp corners, represents the optimum in aggregate for penetration macadam of high type (Group A).
AGGREGATE with soft, rounded corners that crushes under rolling (right), represents the poorest in materials (Group C) for penetration macadam roads.



A TRAP ROCK ROAD with coarse texture finish (left) is a mosaic of clean, stone surfaces, held in place by bituminous binder.
A BITUMINOUS MACADAM road (right) allowed to wear until the small stones are breaking loose; an immediate seal coat will put it in condition.

Summary

1. There are three varieties of bituminous macadam—penetration type—largely distinguished by the quality of aggregate, and with different capacities under traffic.

2. The best way to reduce maintenance costs is by building the surface in sound fashion with due regard to fundamental priniciples.

3. Good foundations and drainage are essential.

4. Lateral support at shoulders should be kept high.

5. The only way to correct a base failure is to find out what caused it, then correct it, and finally reconstruct the base.

6. Surface defects should be repaired only if they impair riding qualities or permit entry of surface water.

7. Patching of the surface should be done with the same size and quality of aggregate and the same bituminous material as used in the original construction so far as possible, in order to avoid differential surface wear.

8. The time for retreatment is when the surface begins to absorb surface water. It is better to make a light treatment more frequently than to risk impairment of base.

9. Amount of retreatment should be only enough to replace surface wear and insure a waterproof condition, except in the case of old surfaces where correction of cross section is desirable.

10. Equipment and labor requirements, while not complex, should call for a high level of efficiency. Maintenance is more an art than a science, and there is no substitute for experience.

Ridding Road Mix of Water

Entrapped water in the mix and capillary water in the subgrade provide the principal maintenance problems of bituminous road-mix surfaces

By B. G. Dwyer

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THE vital fundamentals of road-mix maintenance are, first, proper original construction, and, second, direction of major activities against water in the surface mix and in the subgrade which supports it. There are other factors naturally, but these two stand out in the maintenance problem of bituminous road-mix highways as disclosed by the maintenance in New Mexico of over 1,500 mi. of oil-processed surfaces, the greater mileage of which is of the road-mix type.

Materials important factor

As is described later, road-mix maintenance is preferably a reprocessing operation of the old surface mix with new materials of the same character. The materials of the original construction therefore have vital importance in future maintenance.

The general specifications for mineral aggregate which have been developed and which have proven to be most satisfactory provide for the following requirements by dry weight. Where screened through laboratory screens, the material must be uniformly graded between the sizes below specified:

Percent passing 1-in. circular opening	100
Percent passing 10-mesh screen	40-60
Percent passing 200-mesh screen	8-15

The material passing the 10-mesh in the finished mix should be uniformly graded from 0 to 10 and should meet the following requirements in addition to those specified above:

Field moisture equivalent, percent	Not more than 20
Lineal shrinkage, percent	Not more than 4

Specifications for liquid asphaltic materials have been changed from time to time as better products have been developed. The first roads were built with materials designated in the Pacific Coast Territory as 65+ Road Oil, and by The Asphalt Institute as Asphaltic Road Material No. 3. This material is now designated by The Asphalt Institute as type SC-2. With the development of the different types of liquid asphaltic road materials, experiments were made to determine which were best suited to conditions of construction found in New Mexico. From these experiments it has been found that Asphalt Institute specifications for type MC-3 material meet the requirements successfully.

Asphaltic materials used for seal coating vary with the age and condition of the surface to be sealed. For older surfaces, where it is necessary to fill small cracks, it has been found that the MC types 2 and 3 give very satisfactory results. The selection between these types is governed by temperature conditions. For surfaces where the filling of cracks is not the primary function, it has been found that Asphalt Institute specifications for the type RC-3 produces results which are entirely satisfactory. The tendency of this material is to build up the thickness of the oiled mat, and for this reason it is necessary to cover the surface as soon as it is treated with course sand or stone chips.

From the standpoint of maintenance, the main advantage that the road-mix has over other bituminous types is that it can be taken up and reprocessed to correct surface irregularities, pot holes, etc. It is important then that the grade of the mineral aggregate and type of asphaltic material be such as to permit reprocessing. It is possible to road-mix almost any aggregate with any of the several types of asphaltic materials and get a surface which for the most part will be satisfactory, but, unless the materials are controlled as specified above, when repairs are necessary it may not be possible to tear up the mat and reprocess to make the necessary corrections, and the surface must be patched by hand, which is an expensive procedure compared with the other method.

There are certain factors which have a definite bearing on the maintenance of oil-processed roads, and which must be observed during construction if high maintenance costs are to be avoided. They are: (1) Presence of water in mixed materials (this usually comes about by reason of rainfall during construction); (2) heavy wagon traffic, particularly narrow-tired vehicles; this is detrimental, and it is recommended that on roads where wagon traffic predominates, as it does in some farming areas, some other type be used; (3) high water table where saturated soils are encountered, permitting the entrance of moisture in the bottom through capillarity; (4) presence of clay in the mixture; (5) inadequate side ditches; (6) improper distribution of asphaltic material in the mineral aggregate, and (7) excessive asphaltic material in the mineral aggregate.

The presence of any one or a combination of these conditions will cause surface irregularities and other forms of failure which will require extensive maintenance to correct. Attention is called to Fig. 1, which illustrates a condition whose result has been maintenance costs of over $400 per mile per year. Failure common to the condition illustrated in Fig. 1 is shown in Fig. 3. A comparatively few miles of improperly built road will make a tremendous difference in the maintenance cost of the entire system, which in turn tends to discredit the economy of the use of this type of pavement by those not familiar with conditions.

Organization and equipment

The maintenance organization of the New Mexico state highway department consists of an assistant state highway engineer in charge of maintenance, office assistant, cost engineer, clerk and checker located in the general office in Santa Fe. The field work is divided according to highway districts, of which there are five, each in charge of a district engineer. Each district is divided into maintenance patrols about 75 mi. long, each patrol being in charge of a patrol foreman and from 3 to 5 men. In addition to the patrols, for each high-

way district there is, because of the specialized character of the work and the necessity for men trained in this type of work, an oil maintenance crew which is assigned to each district. This crew is charged only with the maintenance of the surface of the road. Roadside and structure maintenance is assigned to the local patrol. The oil maintenance crew and equipment is made up as follows:

CREW	EQUIPMENT
1 Foreman	1 Oil distributor
1 Distributor operator	1 Car heater
	1 5-ton roller
1 Swamper for distributor	2 Motor graders
	1 Sanding machine
1 Boiler man	4 1½-yard dump trucks
2 Motor grader operators	1 Pickup truck
4 Truck drivers	
1 Roller man	
4 Laborers	

The equipment for patrols assigned to the maintenance of off-surface sections of the road vary according to local conditions, but ordinarily is as follows: 1 motor grader, 1 tractor and pull grader and 1 1½-yd. dump truck. In addition to this equipment there is assigned to each district a small power shovel for use on patrols where it is necessary to widen cuts, clean ditches and build up shoulders on high fills; this work is confined somewhat to mountainous sections, and is of a character which cannot be economically handled with tractor and grader equipment.

Repair methods followed

It has been the experience that, except for small pot holes (which are patched immediately after they form), satisfactory repairs can be had only by tearing up the section of the road to be repaired and reprocessing and relaying it after the base has been allowed to dry out thoroughly. Other conditions which are quite frequently found and which require reprocessing to correct are presence of water in the mixed materials, presence of clay in the mixture, improper distribution of asphaltic material in the mineral aggregate and excessive asphaltic material in the mineral aggregate.

Fig. 2 shows the type of motor grader used for this work. As will be noted, these machines are equipped with scarifier and disk (the disk being mounted just behind the blade), which are used to tear up and pulverize the road-mix material. After this operation has been completed, these machines push up a small section of the material and blade it to one side. Each following grader moves its small portion until the whole mass has been moved into a windrow at one side of the road. The machines turn about and repeat the operation, moving the windrow back and forth until the material has been thoroughly pulverized. If additional oil is necessary, it is added with a distributor. After the oil has been added, and such corrections to the subgrade as are necessary have been made, the material is mixed until the oil is uniformly distributed, then it is spread the required width, after which it is rolled and thoroughly compacted with a 5-ton roller. The above description covers the actual operation for the repair of an oil processed surface.

FIG. 1—SECTION OF OIL-PROCESSED ROAD showing the presence of high water table, a condition which, unless avoided, will result in extremely high maintenance

FIG. 2—TRAINS OF GRADERS are used in tearing up and reprocessing bituminous road-mix surfaces; patching except for small potholes is rarely employed.

There is one other essential operation: the asphaltic material is usually received in tank cars holding from 6,000 to 10,000 gal. These cars are usually the insulated type and the asphaltic material generally arrives at the site of the work at a temperature of about 80 or 100 deg.; to bring the material up to the required temperature, it is necessary to circulate steam through the coils of pipe with which the cars are equipped.

After the completion of repairs in the manner described, it is essential that the surface be protected from moisture from any source. This is accomplished by applying a seal coat of asphaltic material at the rate of about ⅜ gal. per sq.yd., after which sand or stone chips are applied at the rate of about 60 tons per mile. The necessity for seal coating is not confined to sections which have been reprocessed, but is required at intervals of about two years on all oil-processed surfaces as a protection against moisture. In some sections, where conditions of travel justified the expenditure, oil-processed surfaces have been sealed with natural rock asphalt, this material being applied at the rate of about 300 tons per mile, and at an average cost per mile of about $2,500. The use of natural rock asphalt for this purpose has, where the road is properly constructed, materially reduced the cost of maintenance.

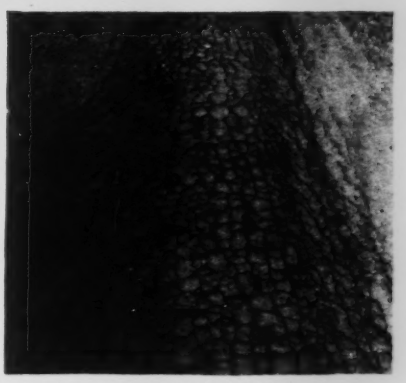


FIG. 3—TYPICAL FAILURE of oil-processed road surface caused by the presence of moisture in the sub-grade. The pencil in the foreground gives a comparison of the size of the cracks.

The average cost per mile for the maintenance of the 1,505 miles of oil-processed roads in New Mexico for the fiscal year 1935-36 will be slightly over $328 per mile. This cost, while high when compared with that of $205 per mile per year for gravel-surfaced roads, is justified by the additional safety, comfort, and service given the users of the road, and also by the established fact that this type of road will economically accommodate traffic equal to at least twice that which could be handled by the gravel-surfaced type.

Waging the Battle with Snow

Attack with veterans of regular maintenance, armed with fast-moving equipment for quick concentration against shifts of storm.

By W. F. Rosenwald

Maintenance Engineer, Minnesota Department of Highways, St. Paul, Minn.

THE EVOLUTION in transportation which has made the nation dependent upon the motor vehicle has also made it imperative that our main highways be open at all times. These highways in most states constitute the highway system which is operated and maintained by the state. In the states subject to heavy snowfalls and severe snowstorms the problem of the open road is entirely distinct from other maintenance problems. Last February in Minnesota many highways were opened four or five times daily, and for as many as seven successive days. During a ten-day period it was necessary to extricate more than 2,000 vehicles either hampered by or completely embedded in drifts.

Anti-drift defenses

The most important factor in the snow problem is the location and design of the highway itself. The physical features of the highway, to a generally unrealized extent, govern the entire snow-control organization as to types of equipment and methods of operation. A highway with flat slopes both toward and away from the roadway, and with wide cuts, offers relatively little inducement for drifts to form. A highway with easy curvature permits faster operation of snow-plowing equipment, which is very essential for economical as well as effective performance. Roads with sharp turns and narrow cuts ordinarily necessitate the use of slow-moving, heavy equipment, which is always expensive. Generally speaking it is much more costly to keep open the roads of early design, in which little or no consideration was given to the snow problem, than the roads of more recent design.

In addition to the design of the roadway, the snow problem can be very materially altered by methods of controlling the position and formation of snow drifts, principally by snow fences or snow barriers of various kinds. The picket-fence type of snow barrier is the cheapest in first cost, is easily handled and is very effective when properly placed in strategic positions. The position of the fence must be determined by experience with the conditions on each particular section of road. Usually the position is on the side from which the prevailing winds come, and anywhere from 75 to 150 ft. back from the road—in some cases even farther away, especially where the winds are generally of high velocity.

The shape and distance of a snowdrift from a snow fence is governed by the space between the bottom of the fence and the ground. With the fence sitting directly on the ground, the drift forms at the fence and it will become buried if the storms are heavy. With the fence raised clear of the ground, the stream of air passing under the fence causes the drift to form farther away and, incidentally, keeps the fence clear and free from being buried by the snow. Setting the fence up from the ground, of course, increases the necessary distance from the roadway. It is desirable to discourage the formation of drifts entirely, but if drifts cannot be avoided then it becomes necessary to control them so that they form in a position where they will not block the roadway.

The placing of snow fence or other barriers is really a method of increasing the snow storage capacity to take care of the snow dropped or deposited by the air current (wind), of which the velocity and consequent snow-carrying capacity are changed by encountering an obstruction or by friction with the ground or other objects over which it flows.

In organizing a snowfighting campaign, it is desirable and best to utilize the organization (men and equipment) which is used in other maintenance operations and is thoroughly familiar with the highways on which it works. In this way it is possible to have a much smoother running organization and also more experienced men. In a snow campaign more than in any other maintenance operation it is necessary to rely on the judgment and discretion of the individual operators themselves and on that of their immediate superiors. The organization must function and begin operations without waiting for instructions from the central office, and oftentimes without waiting for instructions from the district office.

The function of the central office is to move equipment and forces from quiet areas to areas which are in difficulty. The central office works out general policies and principles, but district control must determine, for instance, in each area whether to start operations with the beginning of the storm or wait until the storm has eased up. Possibly some intermediate time will be found most effective. No hard and fast rule can be set up, as each storm differs and presents new factors, involving visibility, the traffic which happens to be on the road, the conditions remaining from a previous storm, the condition of the equipment and the needs of the area. Oftentimes the traffic is completely tied up by the severity of the storm or low visibility, and then unless there are vehicles with people in them which have to be rescued it is better to wait until the storm eases up.

We have storms of such severity that any plowing operations are entirely ineffective and the roads are blocked again almost as rapidly as the plow goes through. Such a storm is hard on both equipment and men, and it can easily happen that an accident or severe use might affect the outfit so that it is inefficient when the storm eases off and it becomes desirable to have the men fresh and the equipment in the best condition. However, there are sections of highway where the necessity of maintaining traffic is so great that operations must start much earlier than is advisable on some of the other highways.

The Minnesota state trunk highway system of 11,339 miles is divided for purposes of administration and control in maintenance into 16 maintenance districts; the mileage in the various districts ranges from 500 miles to a maximum of about 800 miles, the smaller districts being in the metropolitan and more densely populated areas. About half of the total mileage is either paved or has a bituminous surface; the balance is practically all untreated gravel surface; less than 500 miles is unsurfaced.

Each district is under the charge of a district maintenance engineer, who has a district office and repair shop, with outlying garages for housing equipment other than that working out of district headquarters. He has a staff consisting of a general foreman, a traveling field mechanic, and maintenance foremen for field operations; a chief mechanic in charge of the repair shop; a principal clerk in charge of his office, and such office and mechanical help as may be necessary for the operation of the district headquarters office and shop.

The equipment is stationed at various points within the district, working either out of the headquarters shop or out of the outlying garages, and is manned by permanently-employed operators stationed with the equipment. The particular equipment to be used on my specific occasion is determined by the district maintenance engineer and his field staff. The exact moment of beginning operations at any point is largely determined by the operator in charge of the unit, who, however, reports by telephone to the district maintenance engineer as to conditions and for instructions, so that the district maintenance engineer can be considered as controlling the operations at all times. As difficulties become more serious in any section of the district, the district maintenance engineer moves in equipment from less troubled sections from which it can be spared.

The highway patrol in this state is a subdivision of the department of highways, and during winter operations the patrol officers act as messengers and contacts between various controls and equipment in the field, locate and help vehicles which may be in trouble, and are of general assistance to the various maintenance organizations at all times.

It is seldom that a heavy snowfall and storm covers the entire state at one time; ordinarily not over one-fourth or one-third of the state is seriously involved and, to some extent this holds true also within the individual maintenance districts. The storm areas, although frequently confined to about the same quarter of the state during any one winter, over a period of five years appear to cover all sections quite uniformly. This local tendency of storms makes possible the movement of equipment and men from districts from which it can be spared into districts which are in need of additional help. Such moves are made under instructions from the central office. Care is always taken, however, to leave sufficient equipment in the clear districts to meet the possibility of a storm there; and any equipment that is so moved to another district is subject to recall by its home district in case it becomes necessary.

During the past winter the snow situation was serious in the southern third of the state, and the northern portion was comparatively clear; a number of equipment units were moved as far as 400 miles away from home stations, and were gone in some cases for six weeks. It is seldom that slow-moving or the lighter types of equipment are moved from one district to another. Usually it is the more powerful trucks and rotaries that are needed. When outside units are moved into a district, they come under the control of the district in which operated, subject of course to recall by their home district in case a storm develops there.

With the organization so mobile and flexible in operation that needed equipment and force can be moved at any time to troublesome areas, it is possible to carry on successful operations with fewer units than otherwise required.

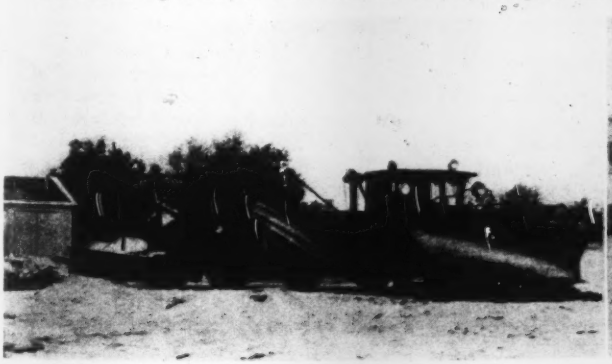
Snowfighting equipment

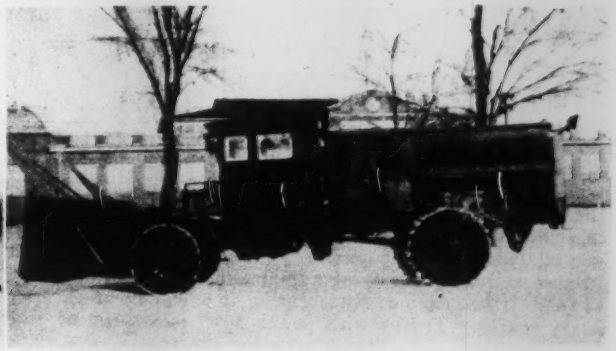
The state-owned equipment available for snow-removal operations in Minnesota consists at present of 114 power graders; 100 1- to 1½-ton trucks; 119 2- to 3-ton trucks; 102 heavier trucks;

MODERN SNOWPLOWING is done at speeds up to 50 miles an hour with this stream-lined plow and wing

SELF-CLEANING ROAD DESIGN is the first line of defense against snow blockade; a high grade line and flat slopes permit snow to blow across the road.

POWERFUL EQUIPMENT UNITS for attack on drifts are plow and wing equipped trucks coupled in tandem and truck-mounted rotary plows.





90 one-way plows; 238 V-plows; 217 wings; and 12 truck-mounted rotary units. There are also 28 crawler tractors, but these are no longer used to any great extent in snow removal operations, except on some of the winding roads which have not yet been improved sufficiently for the use of more efficient equipment. When a situation becomes serious enough and additional equipment is needed, it is usually rented from other owners.

Each district has a number of the larger and more powerful trucks, and as the plowing operations become more difficult these trucks, as well as the intermediate-size trucks, are hitched together in pairs, to make up tandem units, which give increased power behind a snow plow and makes possible higher-speed operation. The rotaries are stationed at various district headquarters, from which they can be moved to any section, and when the situation becomes serious anywhere a sufficient number are concentrated in the trouble area.

The type of equipment to be used and the method of operation are largely governed by the nature of he road and its vulnerability — involving alignment, shapes of the cuts, position of structures, groves of trees and protection against drifting. A road may be well protected against drifts but the alignment may be such that the speed of operation is limited. Naturally there is considerable variation between the operation in open country and in timbered areas.

An important factor in all snowplowing operations is the shape of the plow used. A plow designed for slow operation is entirely unsuited for operation at higher speeds. The slow movement calls for a plow which pushes or rolls the snow to the side, whereas for higher speeds the shape must be such that it will lift and throw the snow and offer the least possible resistance to the propelling power.

The hitch or connection between the plows and trucks should be such that the plows are quickly interchangeable on all trucks, so as to avoid delays when a plow is damaged, which frequently occurs and against which contingency reserve plows should always be available for replacement. Similarly, all cutting edges and shoes should be interchangeable on all plows of the same size.

On the lighter truck units and for the light snowfalls or storms, one-way plows are used; but on the heavier units, V-plows are used almost entirely.

The power available in the propelling vehicle is a very important factor, as suitable speeds for meeting all the conditions encountered are possible only with ample power; care must be used in the selection of units that have motors of sufficient power, and the tendency is constantly for more powerful motors. Minnesota is now specifying a minimum of 450 cu.in. engine displacement in heavy trucks. Trucks with power applied to all four wheels are desirable in many cases, but the amount of power is apparently even more important.

All trucks, except the lighter units, are provided with wings on the right hand side. The experience is that a wing about midway on the side of the truck is more effective than one attached at the front end. Wings should be at least 10 ft. long and so arranged that either end is adjustable vertically; it is important that the outer end of the wing can be lifted rapidly. A winch or other quick-acting device with a power take-off from the truck which is controlled by a lever in the cab is desirable.

The condition of the equipment is always important, and it is necessary to have sufficient shop facilities so that repairs can be promptly made. If motor equipment is tied up for any appreciable time it is necessary to house it in quarters sufficiently warm so the oil does not harden so as to interfere with proper lubrication and, furthermore, so that the motors can be more easily started.

Methods of attack

Light snowfalls can be handled to advantage by power graders and light trucks equipped with one-way blades or plows; as we get into heavier snowfalls and storms, the heavier equipment becomes necessary. A considerable variation, however, exists as to the type of equipment used on any particular section of highway. Some highways, which are naturally well protected, can be handled almost throughout the winter with only light equipment, whereas in the more open country it is necessary to use the heavier equipment much earlier.

The cost of snowplowing varies with the speed of operation. The higher the speed, the more efficient and economical the operation and the farther the snow is thrown away, with simpler methods and less need for clean-up operations afterward. Snow piled up in ridges alongside the road aggravates succeeding storms, unless in the meantime these ridges are eliminated. Only by fast operation of the snow plow and wing can the formation of ridge be avoided. The most effective operating speeds are from 18 to 30 miles per hour. Operations below 15 miles per hour are almost sure to leave ridges and consequently entail a clean-up operation thereafter.

Frequently there are situations where snowdrifts are relatively light, except for occasional large drifts, with miles of almost open road between. These large drifts are usually beyond the ability of the light equipment, which can easily handle the other portions of the road. In such cases rotaries mounted on trucks so that they can be moved rapidly are the practical solution. If a rotary is not available and the drifts are not too deep, tractor-mounted plows can be used, but because of the slow movement of tractors this becomes a very expensive operation unless the tractor can be hauled on a sled or trail to avoid the delays between the drift

An ideal combination on many highways is a truck-mounted plow and truck-mounted rotary working together. Where the drifts are not too heavy, the plow is ahead and the rotary is used for widening and clean-up; and when a drift is encountered that is difficult for the plow, then the rotary goes ahead. With two units working together in this manner, long stretches of roads can be opened in a surprisingly short time, even under the severest conditions.

One of the most important factors in snowplowing operations is cleaning up or removing the snow ridges and widening the open portion. This, of course, must be done after a storm or between storms. Power graders, trucks with wings, and rotaries are used. Much work can be done by the wing alone, leaving the plow off so as to secure faster winging operations. In some cases blade graders have been used to pull down high ridges, then a rotary to throw out this material; rotaries are the most effective means for cleaning up high banks or high ridges alongside the plowed strip.

A trick which is commonly employed by experienced snowplow operators is to break through a blocked road on the windward side of the road, instead of through the middle. This practice, especially in a windy section, makes the subsequent operations much easier, as it is easier to throw or move snow with the wind in subsequent operations.

Obstructions along the road, such as guard rails and bridge railings, frequently become covered or difficult to see, and a good practice is to have the men who will operate the equipment go over that particular section and fasten markers (a plain lath or pole will do) which will project above the obstructions; these markers should be dark in color, so as to show up well against the snow background.

At least two operators are required on a snowplowing unit, and under no circumstances is one man permitted to take out any equipment. As the men naturally are more efficient if they are comfortable, all cabs on snow plowing units are well constructed and heated with hot water heaters. Exhaust heaters are prohibited, because of the dangers from monoxide gas. All equipment is checked over frequently, daily if possible, to guard against breakdowns; and in the checking operation special attention is given to the safety provisions.

Snowplowing operations are carried on day and night until the road is open. When the visibility falls so low that the men cannot see what is in front of them operations are stopped because of the hazards; naturally, operation under such conditions would also be largely ineffective. Widening operations and removal of ridges ordinarily are carried out only in daylight hours, to avoid the

hazards of night operation. In case of frequent storms, however, it may be necessary to carry on widening operations also at night.

The normal working shift is 8 hr., and unless the operation is likely to extend through only one or two shifts arrangements are made to bring relief shifts to the equipment. Sometimes, because of inability to get a relief shift to them the men must work through as much as 24 hours, and even longer. This, however, is avoided because, as the men become exhausted, the hazards increase. When a storm or series of storms necessitates almost continuous operation, it is best to break up the regular operating crew, so as to have one of the old experienced men with each relief crew.

Reference has been made to operating trucks in tandem formation. In such cases the trucks hitched together should be of the same type and power, and the operators of the two trucks must have had considerable experience so that their actions are perfectly coordinated. They must shift gears together and must also similarly apply power and brakes. Signaling devices between the two trucks have been used, but this practice is not especially successful, and usually the action of the operators is governed by the operator in the rear truck watching the operator in front. This works out very successfully, but it requires experience so that the men will read each other's movements.

Snow removal on state highways within cities and villages calls for somewhat different operation from that in open country. Because of the sidewalks and business establishments alongside it is not possible to throw the snow, and it is necessary to ridge it up somewhere between the roadway and the sidewalk. This immediately interferes with access to the business establishments, and it often becomes necessary to remove and haul away the snow, which is so expensive that if the state were to undertake it the available funds would soon be depleted. Consequently the state adheres to a policy of doing the plowing only, and any hauling must be done by the local authorities, either through voluntary contributions or at municipal expense.

Snowplowing operations are also influenced by the temperature, which affects the condition of the snow itself, whether wet, loose or hard. The condition of the snow has a bearing on the type of equipment to be used at the time. Snow which falls during low temperatures is much easier to handle than the wet or heavy snow which comes with higher temperatures. A warm spell followed up by a hard freeze changes the snow to a frozen, icy condition, and it frequently happens during severe snowstorms that the snow becomes packed so hard that it is very difficult to plow. Merely an icy surface over loose snow underneath is not serious; hard-packed snow is the most difficult condition, and one in which light equipment is practically useless.

Safeguarding traffic

Although accidents have been surprisingly few in snowplowing operations, such operations are always dangerous to the operators and to traffic. To minimize these hazards as much as possible, definite markings of the equipment and arrangements of lights are specified.

The front of snowplows (above a horizontal line drawn through the upper end of the nose), the outer 3 ft. of the back of the plows and the outer 3 ft. of the face and back of wings are painted with 6-in. black and yellow alternating stripes, the end or top stripe being yellow. The stripes on the face are vertical, those on the back are horizontal.

In addition to the lamps and flares required by law, i.e., the regular head lamps, tail lights and emergency flares, each motor unit is equipped with: (1) two blue lamps placed near the top of the cab, one at the center facing forward and one at the center facing to the rear; (2) one white floodlight to illuminate the right end of the snow plow and the wing (if any); and (3) one yellow floodlight to illuminate the left end of the snow plow. All these lamps have a lens not less than 8 in. in diameter. At least one yellow reflector is used to supplement the tail lights required by law; red reflectors, because of low efficiency, are not permitted. Any hired equipment which is used is protected and marked in the same manner.

In the early part of the winter icy and slippery conditions are encountered, and the attention of the whole organization is devoted to sanding and cindering operations. The question whether the entire stretch of road is to be treated or only curves and hills depends largely upon the locality and local conditions. In areas where the traffic is dense it is usually necessary to do much more sanding than on the lighter-traffic roads. Sanding along sections encourages higher speeds; whereas sanding only critical points naturally reduces the speed of vehicles to a more cautious rate. Neither method entirely removes danger. Our most hazardous situation, however, occurs where sections become icy from fog or mist passing over them at certain temperatures. As this occurs without warning, and in a very few minutes, it is probably one of the greatest causes of accidents.

In the preparation of sand and cinders for this work, an admixture of calcium chloride or salt is used, which keeps the material in usable condition and helps to prevent its being thrown or blown off the roadway; salt, however, should not be used on concrete pavement, because of the possibility of concentrated salt solution damaging the concrete.

Sanding sections of some length is most economically and speedily done by special spreading machines. Where only critical points, such as curves and hills, are sanded, it can be satisfactorily done by men using small scoops and throwing either from a truck or from stock piles previously placed at the roadside.

Assembling and making available to the public, information as to road conditions is, of course, very important and Minnesota practices the following method.

The maintenance district office reports to the central office by telegraph whenever a highway in the district becomes, or is likely to become, impassable; and also when a snowstorm or snowfall gives indications of causing difficulty to traffic.

The district office during a snowstorm is in touch at all times with all units and sections in the district; and at 9 o'clock every morning, when a storm is under way or when any highway is blocked, a report is telegraphed to the central office, advising as to snowfall, storm conditions and sections of highway which are in trouble; if all are open, the report so states. This information is consolidated in the central office and is immediately available to the public. The broadcasting stations and daily press make special features of this information. On telephone inquiry to the central office or to any of several information bureaus, information as to any particular highway is given.

Snow removal pays

It has been said that money spent in plowing snow leaves no benefits. The manner in which snow is removed and controlled, to a large extent, governs the spring break-up and the effect of the winter climatic conditions on the road surfaces. It is especially important during the latter part of the winter that the snow be cleared off the roadway sufficiently wide so that when the spring thaws come the snow is immediately drained away without running over the roadway surface or shoulders. Where the snow is in such a position that the melting snow runs along the roadway or the shoulders it is apt to penetrate to the subgrade, softening it up, with the natural results which occur from a softened subgrade.

The snow expense on the Minnesota trunk highway system, including the purchase, erection and taking down of snow fence, ranges from a low average per mile in 1931 of $28.93 to the high in 1927 of $125.04. The expense to date in 1936 is nearly up to the 1927 figure, and will undoubtedly exceed it when next November and December are added.

The receipts from tax on gasoline during the winter months of December, January, February and March are about $157 per mile of highway in the system.

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Interstate Flood Control

THREE STATES, Minnesota, North and South Dakota, have sent to President Roosevelt a program for group action to conserve the water resources of the Red River of the North. The program is the first definite one to come out of the work of the National Resources Committee. It it accompanied by a list of projects, with priorities and estimated costs, also a statement that the states are willing to bear part of the cost if the federal government will bear the remainder as part of its work relief program. The three states are setting up a tri-state organization to maintain and operate the proposed facilities. This is an encouraging development for several reasons. In the first place it shows that the control of an interstate stream is not so difficult as to require the work to be carried out by the federal government. It shows further that the states recognize their local responsibility in indicating that they will bear part of the cost and will take over operation and maintenance after the regulating works have been constructed. The fact that the planning commissions of the three states have gotten together on a definite and practical program also is encouraging. Too much of our resource planning has been up in the clouds, voluminous reports and little else. It is to be hoped that the leaven of this concrete action will spread quickly to many other states. Congress has authorized large expenditures for flood-control work. It may be expected to include in its first appropriations those projects that are ready to start.

The Circus Come to Construction

A HUGE NET, 4,200 ft. long and 110 ft. wide, according to reports, will soon be hung from the cables of the Golden Gate Bridge, to catch anyone who may fall during the erection of the floor and stiffening truss steel or the placing of the roadway slab. Such a dramatic safety precaution is fittingly inaugurated on the Golden Gate Bridge, since it is reported that so far not a single life has been lost on this job. Few if any large construction projects can boast such a record. In spite of the substantial advances in making construction work safer, we still expect large jobs to exact a toll of human life; one death per million dollars expenditure is often quoted as an average. The Golden Gate record thus seems almost incredible, but why should it? Other industries have overcome reputations for poor safety conditions, and in fact the construction industry has improved its bad name in this respect by better education, improved equipment and better safety appliances. Perhaps, however, it is time to begin thinking of more drastic methods, so that no fatality will be regarded as predestined. If the $80,000 expenditure for the Golden Gate Bridge net saves even one life, it will be worthwhile; if the net is never called upon to check a death fall, its cost, a negligible expense item on a $35,000,000 project, will still be justifiable insurance. Bringing the circus to construction by adopting its safety net is a significant happening indicating as it does the ability to think of construction safety in terms of large-scale correctives. Perhaps by making construction safety spectacular, the net will aid in making its importance real.

A Good Work Started

A RECENT REPORT that nearly three-fourths of the states of the Union are now cooperating with the federal Bureau of Public Roads in a complete rural highway planning survey is excellent news. The principle that highway development should proceed according to a plan covering a period of years and based on economic and social needs has long had advocates but few practitioners. Generally the reason has been that public road officials have not had the facts on which to base a plan. Considering the roads of a state as a whole, present-condition inventories are few; surveys of density, distribution and financial status of population and classification of property have been rare; incidence and amount of highway taxation has been determined for only a handful of states and even knowlelge of traffic is by count rather than by surveys of kind, character and movement broken down into usable elements. Under such conditions long-period budgetary planning has been impracticable; indeed not enough evidence has been available to sell to legislators the idea of such planning. From this handicap a way of relief shows promise of being cleared by the survey now being so widely undertaken. The work should be supported by every element of highway transport and every state not now cooperating should be induced to join in making the survey nationwide.

Why Force Account?

THE HOUSING DIVISION of PWA has threatened to resort to force account on its remaining projects because contractors, so it states, are bidding too high or else they are not bidding at all. The situation merits close scrutiny, for there is something obviously wrong when contractors, hungry for work, refuse to bid on large building jobs, and particularly when the contracting body, getting no bids says, "All right, we'll build it ourselves." These are large, complicated jobs, wholly unfitted to force account. Costs instead of being reduced would almost certainly be increased, and low-cost housing cannot stand any further increases. Perhaps the bids that the Housing Division is getting are too high; it would be surprising if they were not, considering the lack of competition and the onerous requirements of the PWA, the cost of which the bidder must cover in his bid. Everyone, it seems, recognizes that the requirements are unreasonable except the PWA. When as many as 150 alternates are provided for in a specification, when tolerance limits are not defined but in practice approach unattainable perfection, when inspection is entirely divorced from design and specification writing and when the right to discharge incompetent labor is denied the contractor without the engineer's approval, it is not surprising that contractors do not rush to bid. If the PWA wants lower-cost housing, it can no doubt get it by a revision of rigid rules. Furthermore, it can get first class workmanship without evoking the police power. Contractors have reputations to maintain the same as government officials, and it is not human nature to risk these reputations by building shoddily on projects that will be so much in the public eye. Low-cost housing is already bedeviled by so many obstructions that it is a pity the actual construction work cannot be carried on efficiently and expeditiously. We believe it could—and at less cost—if the PWA would look under its own

hed for the culprit instead of gunning for the contractors with the emotional threat of building by force account.

Spy System Abandoned

THOSE HAVING PWA work under way or in prospect will welcome the change that has taken place in the PWA inspection system, not because it means the lowering of bars against poor workmanship, but because it means improved morale and fewer petty annoyances. Apparently the Administration has come to realize that its espionage systems, set up in a well meaning effort to prevent graft and scandal, breed more trouble than they prevent. Those who were responsible for setting up the spy-system claim that it has kept the PWA free from scandal, but its achievements on this score can hardly be classed as outstanding. In all the cases in which the PWA has publicly charged its engineers and others with reprehensible acts, an open investigation has resulted in vindication of those against whom charges were preferred. Witness the Willacy case. The morale of the PWA staff would be higher if credit for the freedom from scandal were given to the high standards of the men picked to carry on the PWA construction activities instead to the secret agents. The present change should prove salutary. It reflects credit on those who brought it about.

Still Unsettled

NOWHERE is the unsettled state of power policy questions more apparent than in the Pacific Northwest. There, in a region whose rate of electric energy use is near the top of the list, the prospect of Bonneville Dam, and perhaps later Grand Coulee Dam, adding to the available supply attracts the attention of large power consumers, who would like to figure on industrial possibilities, and also causes present power suppliers to wonder whether they can go ahead with normal business planning or whether they must expect to see the new plants steal their business away. But none of these questions is yet capable of answer, and the unsettlement is hurting business in that region.

There is no one with authority to say whether or when the new power will be available, at what rates it will be sold, and whether its development will be forced or will be carried on only in proportion as new business develops. If Bonneville power is to find a market when the generators are ready to run, these necessary preliminaries to marketing must be decided long in advance. To leave them undecided helps nobody; it does not help existing power producers and users, it does not help the public—and it does not help the government.

For three years a national power policy committee has been sitting in Washington. To deal with questions of precisely this kind would seem to be the most immediate job of such a committee, but the committee has done nothing about them. In fact it has done nothing at all. As a result no one knows whether the new power will be made an instrumentality for building up the region in which it is produced, whether it will be so administered as to develop local hives of industry, whether it will be coordinated with existing power services and business practices—in brief, whether it will be made a constructive force operating for progress or whether it will become an agency of disturbance.

Heretofore it has been claimed by the supporters of the government's emergency power-plant construction that the new plants will add to the country's productive machinery and will promote growth and progress. These claims have been widely accepted, and all those who believe that widely available power should increase human efficiency and decrease toil and drudgery have looked forward to seeing the construction of the plants followed promptly by action to gear them into the world's work. The continuing inaction with respect to power marketing and policies raises serious doubt whether such hopeful expectations are justified. On present showing the government power plants are a disappointment through failure to declare policies; continued inaction is likely to make them a national sore and scandal.

Though tardily, the unsettling effect of the government's lack of policy can yet be remedied. But it will take more vigorous and better-judged action than has yet marked the power-project adventure.

Time to Act

INDICTMENTS BROUGHT AGAINST six men by the grand jury investigating the collapse of an apartment house in New York City on June 19 indicate that the committee of experts that examined the wreckage came to the conclusion that both the design and construction were faulty. The architect, masonry contractor, and building inspectors are among the men charged with second-degree manslaughter, thus implying that the whole system by which the public expects to obtain protection against such accidents was found to have broken down.

First there is the building code. New York's code like that of many other cities, has loopholes that favor the speculative builder and it does not call for the high type of inspection that is believed to be essential to any large building operation. But it has not been possible to eliminate the defects, chiefly because those who profit by a low grade code or one that is not properly enforced were more influential than those who sought to improve the code. The stock argument of real estate interests that stiffening the building code would stifle building construction had more effect than the possible calamities pictured by those who saw danger in the code's defect.

The apartment house collapse in the Bronx on June 19 may bring about the needed changes in New York City's building code. But an improved code alone will not assure the necessary safeguards. Licensed architects and engineers must be required to sign an affidavit after the job is completed that it corresponds to the plans in every particular. Most important, there must be an end to selling of plans and the substitution of selling of services. With such services should go continual field inspection on the part of the designer, the same as is common practice on bridge work. The cost of such extra service is almost negligible but that is beside the point. We must build safe buildings or not build at all.

Already, as a result of the Bronx accident, architects and engineers in that borough have set up a committee to take up revision of both state and city laws affecting building construction. But city-wide action is needed. Engineers and architects will not be living up to their public responsibilities if they do not act promptly and effectively in this matter. They can obtain needed changes in state and city laws if they press for changes while this accident is still fresh in the public mind.

CURRENT NEWS

Funds for Flood Control Surveys Allocated to Army Engineers

Allocation of funds totaling $1,200,000 for surveys in connection with flood control projects were announced by the War Department on July 29. The allocation was made by the President from new relief appropriations. The projects are as follows: Merrimac River basin, $150,000; Connecticut River basin, $150,000; South Central New York projects, $325,000; Susquehanna River basin, $100,000; Pittsburgh flood control projects, $200,000; Clendenning and Big Bend projects, $50,000; Los Angeles flood control, $75,000. A reserve of $150,000 has been retained by the Corps of Engineers for future allocations.

Six-Year Program Recommended In Planning Public Works

Carrying out a recommendation embodied in the recent progress report of the National Resources Committee (*ENR*, July 16, 1936, p. 98), Secretary Ickes has written to the planning boards of the various states asking their cooperation in preparing a program of public works covering the next six years.

In his letter the Secretary stated: "The National Resources Committee has consistently advocated the advance planning of public works construction. It has seemed advisable that such programming should be done by the localities immediately concerned, and in the form of a six year budget of construction projects, arranged in order of priority and continuously revised and kept up to date.

Flood Control Contractors Organize New Association

Representatives of heavy construction outfits who hope to build flood control works for the federal government in all parts of the United States within the next ten years under the Overton bill and the Omnibus flood control bill, on June 30, organized the National Waterways Contractors Association at a meeting in Memphis, Tenn. The new organization replaces the Mississippi Valley Flood Control Branch of the Associated General Contractors of America. It will be an Independent organization with unlimited territorial jurisdiction, but will continue to be affiliated with the Associated General Contractors of America.

The following officers were elected: president, D. D. Coleman, of Memphis; manager, Fred D. Benecke, of Memphis; vice-president at large, C. D. Ford, of Dyersburg, Tenn.; vice-president for the hauling group, Frank Stanford, of Memphis; vice-president for the tower excavator group, T. J. Clarke, of Clinton, Iowa; vice-president for the dragline group, C. I. Jones, of Baton Rouge, La.; vice-president for the hydraulic dredge group, A. Guibet, of New Orleans, La.; vice-president for the dike and revetment group, Bart C. Tully, of Memphis.

First PWA Grants Under New Program

Grants for 352 projects, to cost about $51,000,000, made to sponsors guaranteeing 100 per cent relief labor

GRANTS totaling $22,742,034 and loans of $2,142,000 were made by the PWA this week for 352 projects having an estimated construction cost of $50,774,196. Grants represent 45 per cent of estimated cost and are the first to be made under the new program. Congress has provided $300,000,000 to be made available in grants out of the proceeds from the sale of securities purchased by the PWA in financing non-federal projects in the past.

This initial list of approved projects includes only those in which the municipalities sponsoring them have been able to certify that 100 per cent relief labor is available for their execution. This is not a hard and fast requirements, but applicants for grants which are able to satisfy PWA on this point will receive preference. The initial list of projects does not include all which have certified that 100 per cent relief labor can be employed on the job but constitutes a group that could be submitted immediately to President Roosevelt for clearance. Projects for which lower percentages of relief labor are available will eventually be submitted to the President for approval.

Initial requirements link the new public works program very definitely to relief needs in other respects. Allotments to approved projects are made subject to fulfillment of a pledge by the sponsor that work can be started by Oct. 1 and completed within one year. The bulk of the projects so far approved are small; only 125 exceed $100,000 in cost, and 52 projects are for less than $25,000. Last year this cost of $25,000 was used to mark the dividing line between PWA and WPA work, but it no longer has any significance. All PWA projects, no matter how small, will be executed by contract.

Highway Department Halts Jobs After Labor Trouble

On July 18, and again on July 20, work on a number of bridge jobs in Des Moines and Boone, Iowa, was forcibly stopped by men stated to be labor union agitators. When local public officials failed to take action, the state highway department shut down the job.

A statement issued by the highway department said, in part: "Proceeding in full conformance with the rules and regulations of the federal government and on due approval of the proper federal authorities, the highway commission has let contracts for all the projects . . . in Des Moines. The contractors on all these projects were proceeding in strict conformance with their contracts. On Saturday, July 18, a large group of men, allegedly residents of Des Moines, appeared at each of these structures, stopped the work and chased the contractor's employees off the job. On Monday, July 20, a similar though smaller group of men again stopped work on the Dallas County bridge. Therefore, the Highway Commission has reluctantly taken the following action:

"1. That it is the desire of the commission that construction operations on [the affected projects] be shut down until such time as it may appear that the contractor will be permitted to proceed under his contract . . . without interference with his labor relations.

"2. That no bids be received or contracts awarded for the construction of proposed projects until such time as the commission may have satisfactory evidence that the contractor will be permitted to proceed under his contract . . . without interference with his labor relations.

"3. That should the conditions in Des Moines continue until Sept. 1, 1936, to be such that the contractors . . . cannot proceed under their contract to carry on their work without interference with their labor relations, and should the contractors for these structures so request, the commission will take action to cancel the contracts for these structures.

"4. That in the event no contract is entered into for proposed structures within a reasonable length of time and should the contract for work now under way be cancelled as provided herein, the commission will recommend that the funds which were allotted to these structures in Des Moines be reallotted for expenditure elsewhere in the state."

Broken Main in Chicago Floods Post Office and Station

An early morning break in a 36-in. water main, 40 ft. under ground, at Harrison and Canal streets, Chicago, flooded the basement of the New Post Office and Union Station, put out of commission two power plants serving the station and kept more than 60 trains from entering. Wood block pavements in the basement and driveways were floated out of place.

The break was found to be at a point where the main from the Harrison St. pumping station, a short distance to the west, passes under a wall at the southwest corner of the post office. The pipe is in a concrete cradle and a plank over the pipe and under the wall may have transmitted breaking vibrations to the pipe. Both Canal St. and Harrison St. are double deck streets at this point. The break poured water onto the railroad tracks under the post office (this being an "air rights" building) along which the water ran to the station, two blocks to the north. Within a few hours the water was 7 ft. deep in the post office and had put all service facilities in the station basement and train floor out of commission. Lack of current disabled the switches and signal systems on the north side of the station.

SEVEN TAMPED-EARTH houses are being built at Gardendale Homesteads near Birmingham, Ala., a Resettlement Administration Project. Earth for the houses is dug out of the yards surrounding the house and mixed in the proportions of 65 per cent of clay to 50 per cent of sand, placed in a form, and tamped with light, rapid blows of a tamper. Recent experiments at South Dakota State College (*ENR*, July 9, 1936, p. 44) indicated that, although earth rich in clay gave higher early strength, earth containing 75 per cent sand had better weathering qualities and increased more rapidly in strength with age. At the Gardendale project no surfacing is used on the walls except for a coat of linseed oil; a stucco covering may be added, however, if desired. Thomas Hibben, Resettlement Administration architect on the project, states that the cost of the tamped earth houses per unit is less than one-fourth that of a concrete house of the same proportions.

Architect and Builders Arrested in New York Building Collapse

Six men were indicted for manslaughter on July 24 by the Bronx County grand jury which has been investigating the collapse, on June 19 (*ENR*, June 25, 1936, p. 930), of an apartment house in the Bronx, New York City, in which 18 persons were killed.

Those indicted and subsequently arrested are: Harry B. Rutkins, architect; Louis and Max Steinberg, builders and owners; Albert F. Heine, an inspector of masonry and carpentry in the Bronx bureau of buildings; Michael de Thiede, a plan examiner in the bureau of buildings; and Vincent A. Vallentine, a masonry contractor who had the masonry contract for the building.

District Attorney Samuel J. Foley is reported to have said, "A few days ago I took a piece of the mortar in my hand and it crumbled like dust . . . The mortar had a disproportionate amount of sand. I also found steel beams that had holes in them, and some of us believe that the steel specified was not used everywhere it was called for.

"This building was so defective in design that even if 100 per cent workmanship and materials had been put into it, the building had to fall."

Committee to Study Long-Term Drought Program

The President, on July 22, appointed a Great Plains Drought Area Committee to prepare a long-term program for adapting life on the Great Plains to persistent drought.

The President, in his letter to the members of the committee, stated: "We have supposed that the modes of settlement and of development which have been prevalent represented the ordinary course of civilization. But perhaps, in this area of relatively little rain, practices brought from the more humid part of the country are not most suitable under the prevailing natural conditions. At any rate, circumstances made it obvious that relief activities are not sufficient and that a competent study and recommendation are desirable."

The committee will not make any new research, but will bring together information on hand in the various departments of the government. Its report to the President will outline and weigh according to their relative importance the various steps which can be taken in the execution of a long term program. The committee's recommendations will deal principally with water conservation and with changes in the economy of agriculture in semi-arid regions.

The members of the committee are: Morris L. Cooke, director of the Rural Electrification Administration, chairman; John C. Page, acting director of the Reclamation Bureau; Col. Richard C. Moore, division engineer, Missouri River division, Corps of Engineers; Frederick H. Fowler, director of the drainage basin study of the National Resources Committee; Rexford Tugwell, administrator of the Resettlement Administration; and Harry Hopkins, administrator of the Works Progress Administration.

Engineer Registration Board Appointed in Alabama

In accordance with the terms of an act passed in the last session of the Alabama legislature requiring the registration of all engineers and land surveyors, a state board of registration has been appointed. The act, patterned after those of other states, provides that at any time within a year after it becomes effective, any professional engineer or land surveyor who shall submit to the board satisfactory evidence that he is of good character, has been a resident of the state a year preceding his application, and was practicing engineering and land surveying at the time the act became effective, shall be granted a certificate. All others desiring certificates must take an examination provided by the board.

The membership of the registration board is as follows: A. C. Polk, chairman; J. A. C. Pallan, vice chairman; R. A. Polglade, secretary; J. D. Converse; John M. Gallalee.

Drought

Washington Correspondence

LITTLE CHANGE in drought conditions is reported by the Weather Bureau. Scattered showers over the northern Great Plains have not checked the spread of desolation. East of the Mississippi River the situation has been improved by fairly good rains, which have brought relief in Ohio, southern Indiana, Kentucky and Tennessee.

Precipitation is scanty, and both surface and ground waters are approaching previous minimum records. Reports of shortages in public water supplies are becoming more frequent, and the situation in many localities will become acute unless heavy rains fall soon. Reports received from the district engineers of the United States Geological Survey furnish a state-by-state description of prevalent conditions:

Nebraska and the Dakotas

Acute shortages in water supply are occurring in a few South Dakota towns in the eastern part of the state, where supplies are obtained from surface streams. The supplies from deep wells are adequate. The flow of the Missouri River, on July 18, at Bismarck, N. D., was 11,300 sec.-ft., and at Omaha, Neb., 21,000 sec.-ft. as compared with 9,420 sec.-ft. and 18,500 sec.-ft. on the same date in 1934. The flow of Missouri River tributaries in South Dakota and, below Bismarck, in North Dakota is less than in the same period of 1934.

Minnesota

Many of the small streams in the western part of Minnesota and in the Red River basin have ceased to flow. Municipal water supplies remain critical, and emergency measures are being planned. In the Mississippi River basin the flow has dropped to practically the same volume as at this time in 1934. Army engineers have released stored waters from the reservoirs to raise the regulated pools to navigation levels.

Missouri

No reports of serious water shortage in Missouri have been received. Although streams are very low, few have gone dry, and the towns have had sufficient storage capacity to supply their needs up to the present time.

The flow of the Mississippi River has been steadily decreasing for some time. At St. Louis, on July 25, the stage was —1.2 ft., 0.8 ft. lower than any previous July stage. The average flow for the week was 59,000 sec.-ft., as compared with 82,000 sec.-ft. for the same period in 1934. At present the discharge is well above the 1934 minimum of 35,200 sec.-ft.

Ohio

The state department of health reports water shortages in eleven Ohio cities. With one exception all of them are fed by ground water supplies, and the shortage is caused by the increased demand due to drought rather than by failure

of deep wells. No shortages in surface water supplies for industrial uses have been reported. Shortages for farm use are general, as shallow wells and ponds are drying up.

Indiana

Restrictions on water use and hauling of water for domestic use and stock continue in a few localities in Indiana. Wells are being drilled in some towns and villages, but no serious shortage is known. Temperatures have moderated and good rains have fallen recently over large sections of the state.

Tennessee

Frequent rains over the state have increased stream flow in Tennessee. Water supplies are now at or above normal, and no shortage of water is being experienced either for municipal or industrial purposes.

New York

Drought conditions are not extremely severe in New York but will become acute unless substantial rains fall within another month. The water supply situation has not been dangerous because most cities are protected by large reservoirs, but rivers are very low and falling rapidly, and heavy rains are needed to restore stream flow and ground water supplies. The Susquehanna at Conklin, above Binghamton, draining 2,240 sq.mi. had a flow July 24 of 257 sec.-ft., as compared with 231 on the same date in 1934.

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SOCIETY CALENDAR

ILLUMINATING ENGINEERING SOCIETY, annual convention, Buffalo, N. Y., Aug. 31 to Sept. 3.

CANADIAN GOOD ROADS ASSOCIATION, annual meeting, Charlottetown, P.E.I., September 1-3.

PUBLIC WORKS CONGRESS, joint meeting, AMERICAN SOCIETY OF MUNICIPAL ENGINEERS AND INTERNATIONAL ASSOCIATION OF PUBLIC WORKS OFFICIALS, Toronto, Ont., September 28-30.

CANADIAN INSTITUTE OF SEWAGE AND SANITATION, Royal York Hotel, Toronto, Oct. 1-2, 1936.

INTERNATIONAL CONFERENCE ON STEEL CONSTRUCTION, Berlin, Germany, Oct. 2-7.

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING, second congress, Berlin, Germany, Oct. 11.

AMERICAN WATER WORKS ASSOCIATION, CENTRAL STATES SECTION, Cleveland, Ohio, Aug. 19-21.

ENGINEERING INSTITUTE OF CANADA, maritime general professional meeting, St. Johns, N. B., Aug. 27-29.

AMERICAN WATER WORKS ASSOCIATION, ROCKY MOUNTAIN SECTION, Denver, Colo., Sept. 21-23.

NEW ENGLAND WATER WORKS ASSOCIATION, annual convention, New York, N. Y., Sept. 22-25.

AMERICAN WATER WORKS ASSOCIATION, NEW YORK SECTION, fall meeting, Saratoga Springs, N. Y., Oct. 22-23, 1936.

ASSOCIATED GENERAL CONTRACTORS OF AMERICA, GEORGIA BRANCH, elected the following officers: President, J. J. Jones, Atlanta; 1st vice-president, W. G. Miller, Atlanta; 2nd vice-president, Edmund F. Cook, West Point; secretary, C. M. Kennedy, Atlanta; treasurer, J. Frank Bell, Atlanta.

EXAMINATIONS for registration as Engineers, Land Surveyors and Architects will be held as follows:

NEW MEXICO, examination for professional engineers and land surveyors, Santa Fe, Sept. 12.

Contractor Held Liable For Wages on Subcontract

New York Court holds comptroller may pay wages owed by subcontractor out of funds due contractor

THE New York State Court of Appeals handed down on June 30 a decision ruling that the state comptroller may withhold money due a general contractor and use it for payment of wages to the employees of a subcontractor under him, if the subcontractor fails to meet his own payroll.

The decision is based upon Sections 220-a and 220-b of the New York State labor law of 1932. These sections authorize the comptroller to deduct from the whole amount due the general contractor such sums as may be necessary to meet wage payments due and unpaid on account of work under the contract, regardless of whether the non-payment is the fault of the general contractor or of a subcontractor on the work.

The case just decided arose out of the construction of an addition to the Gowanda state hospital at Helmuth, N. Y. Contract was awarded early in 1933 to Haglin Company, Inc. and Winston Bros. Company, Inc., as general contractors. Painting and wood finishing work was sublet by the general contractor to Fred C. Schottin, Jr. The subcontractor defaulted his contract in February, 1935, owing at the time some $1,700 in unpaid wages. The comptroller withheld $2,000 from the estimate money due the general contractor, whereupon the latter appealed to the court. The supreme court of Erie County in March, 1936, upheld the action of the comptroller. The case was then appealed by the general contractor, the higher court upholding the decision of the Erie County supreme court.

These decisions uphold an opinion by the attorney-general to the Department of Public Works given in March, 1933, in which it was held that: "There being no privity between the subcontractor and the entity letting the contract, such subcontractor is merely considered as agent of the principal contractor. Any dereliction of duty on the part of the subcontractor . . . would be imputed to the principal contractor."

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No Fraud in Buffalo Sewers, Grand Jury Decides

A Federal Grand Jury at Jamestown, N. Y., which has been investigating charges of fraud arising out of the contracts for the engineering on the Buffalo-Niagara Falls sewer projects since July 21, returned no-bills on July 24.

The case arose out of charges that city officials had attempted to conspire with engineers previously connected with the project to increase the bids for engineering services in order to cover costs to the city of promoting the project.

Duggan Resigns Presidency Of Dominion Bridge Company

George H. Duggan, Canadian engineer and industrialist, has resigned from his position as president and managing director of the Dominion Bridge Co., and of its subsidiary, the Dominion Engineering Works, Ltd. He will continue as chairman of the board of the two companies and as a member of their executive committee.

Mr. Duggan became connected with the Dominion Bridge Co. in 1886, becoming chief engineer in 1891. He has been president of the Dominion Bridge Co. since 1919 and president of the Dominion Engineering Works since its organization in 1920. Mr. Duggan has been associated with many of the larger bridge construction projects in Canada, including the Quebec Bridge and the Montreal Harbor Bridge. He is a past president of the Engineering Institute of Canada.

Mr. Duggan will be succeeded in the presidency of both companies by W. E. Angus, now vice-president of those companies, also an engineer.

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Washington Highlights

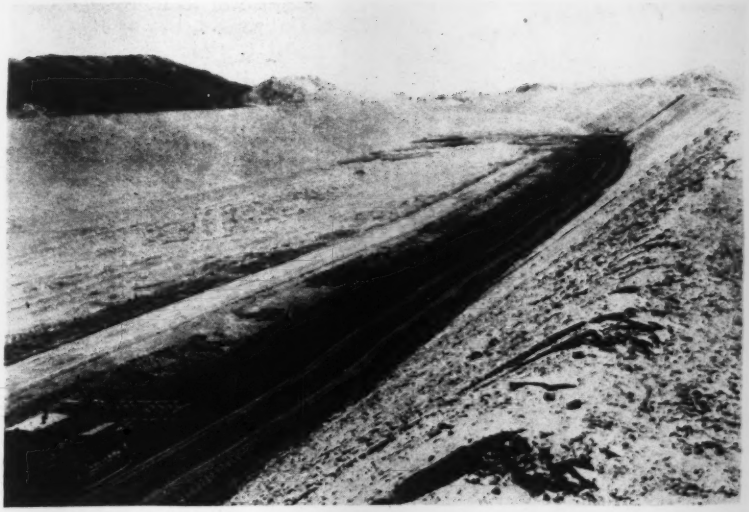
Erection of steel on the new building for the Board of Governors of the Federal Reserve System is progressing rapidly. The board expects to occupy its new building in June of next year.

Various government agencies that have been developing a coordinated flood control program for New York and Pennsylvania will submit to President Roosevelt by August 5 a list of projects on which preliminary work can be undertaken with WPA labor. Plans will be drafted and preliminary work done in anticipation of the award of contracts when the next Congress convenes in January to consider an appropriation bill.

No new survey or investigation is being made of the Florida ship canal. Statements in the daily press to the effect that a new investigation is in progress are thought to have grown out of the fact that the Chief of Engineers has returned to the district engineer a report made in 1934 to have inserted costs and other data which are now available as a result of the work done.

A survey of a ship canal across Florida was authorized by Congress in 1930 and a report was submitted to the Board of Engineers for Rivers and Harbors in 1934. Local interests, learning that the report from the district engineer was adverse, asked that the board delay consideration of the report until they could have an opportunity to gather additional data. Before gathering of new data had been completed, actual work on the project was begun with relief funds. It will now be possible for the district engineer to substitute actual figures for many of the estimates contained in the original report.

The name of Jabez G. Gholston, director of the PWA engineering division, was incorrectly given as Holston in this column on July 23, 1936, p. 136.



LINING A SECTION of the All-American Canal with clay. Over 40 miles of the 80-mile All-American irrigation canal in southern California have been excavated.

Louisiana Registers General Contractors

All general contractors must pass examination and establish financial responsibility to do work in state

AN ACT of the Louisiana legislature, which became effective July 28, provides for registration of all general contractors doing business in the state. A board is set up under the act which will pass on the knowledge and financial responsibility of contractors seeking registration, issue certificates of registration, and have authority to revoke such certificates after a hearing. Contractors not holding certificates are barred from construction work. No provision is made in the law for exempting contractors now in business from the necessity of examination.

General contractor defined

Under the terms of the act a "general contractor" is defined as one who "for a fixed price, commission, fee, or wage, undertakes to construct or superintend the construction of any building, highway, sewer, grading or any improvement or structure where the cost of the undertaking is $10,000 or more."

An examining board will be appointed by the governor. The membership will be made up of contractors with at least ten years' experience, one each from the field of highway construction, public utility construction, and building construction. The first board members will receive certificates of registration from the governor, and thereafter no one shall be eligible for appointment to the board unless he holds a certificate.

The act provides that the board shall meet within 30 days of its appointment to receive applications for certificates, and thereafter at least twice each year. Any time five or more applications are filed, the board must hold a meeting within 30 days to act on them.

Any person or corporation desiring to engage in general contracting in the state must submit to an examination, which may be written or oral, and which may last as long as three days, at the discretion of the board. The examination will be aimed to discover the applicant's knowledge of and experience in contracting. It will cover such matters as reading of plans and specifications, estimating costs, principles of construction, ethics, and so forth. The board will investigate the financial responsibility and past record of all applicants. A corporation making application for a certificate shall designate an officer of the corporation to stand the examination in behalf of the corporation.

The board has the right to revoke certificates of registration when a general contractor is "found guilty of any fraud or deceit in obtaining a license, or gross negligence, incompetence or misconduct in the conduct of his business." Such revocation must be preceded by a hearing, at which the contractor in question has the right to be present, and is subject to review by the court.

The act carries a penalty of $500 fine or six months' imprisonment or both for practicing general contracting without a certificate of registration.

Exemption from the law is provided for "an authorized representative or representatives of the United States government, the state of Louisiana, or an incorporated town, city or parish in Louisiana, provided that such corporation shall be under the supervision of a licensed architect or engineer."

PWA Board Will Consider Federal Projects Only

The advisory board appointed by Public Works Administrator Ickes to consider charges against contractors concerning whom evidence has been received indicating fraud or attempted fraud in connection with bids or contracts (*ENR*, July 9, p. 64), will concern itself only with cases arising out of PWA Federal projects. PWA non-federal projects are not affected by the order according to Secretary Ickes.

Water Conservation Projects On Red River of the North

The state planning boards of Minnesota, North Dakota, and South Dakota, in cooperation with the National Resources Committee, have developed a group of projects designed to conserve water in the basin of the Red River of the North. The proposed work includes construction of small dams, restoration of natural lake levels, channel improvements, flood control, reduction of stream pollution, and improvement of municipal and rural water supplies. The planning boards urged adoption of the schedule as a basis for work-relief employment, and have advised the federal government that the states are willing to contribute a share of the cost. They are now setting up a tri-state organization to operate and maintain existing and contemplated works under a unified plan of water management.

This program, in the opinion of Secretary Ickes, is the first proposal of a practical nature for the execution of a water conservation plan as a major corrective for serious drought conditions.

The cost of the work would be about $10,000,000. The projects are divided into two groups, those of immediate importance, which should be started at once, and those on which studies have not been completed and which should be postponed. Other meritorious but less urgent projects have been specified as part of the general plan. The projects which, in the opinion of the Tri-State Committee, should be started at once, include: water conservation dams on the Ottertail and Pelican rivers, $244,000; control works for channel improvements on the Red Lake river, $437,200; channel improvement on the Red River, Cheyenne, and Ottertail rivers, $355,000; flood control and game refuge reservoir on Lake Traverse-Bois des Sioux, $900,000; Blooming Valley reservoir and Two Rivers auxiliary channel, $1,301,000; small dams for water conservation and recreation throughout the basin, $436,400; municipal water supply and water treatment works throughout the basin, $2,358,600; sewerage and sewage treatment works throughout the basin, $2,546,000.

Personals

SAMUEL KILLAM has been appointed deputy chief engineer of the water division, Boston Metropolitan District Commission. Mr. Killam has been connected with the Metropolitan Water Board since 1897, and has been in charge of the distribution section since 1908.

HERMAN F. BRUMM, formerly principal grade separation engineer of the New York State Department of Public Works, has been appointed district engineer of District No. 6 of the division of highways in the department.

L. O. EMERSON, state engineer for the South Carolina Emergency Works Administration, has been appointed state consultant to the water resources committee of the National Resources Committee.

ARTHUR J. BULGER has been appointed director of the engineering division of PWA, succeeding Jabez G. Gholston. Mr. Bulger has been assistant director of the

division since the establishment of PWA in 1933. He is a civil engineering graduate of the Harvard Engineering School, Class of 1922.

SAM D. BAILEY, area engineer for the Dennison, Ohio, area in the flood control and water conservation work in the Muskingum watershed, has been transferred to the Red River flood control project in Texas.

LORNE MCDONALL has been appointed chief inspector for the Dominion government on highway work and other relief undertakings in the province of Ontario.

C. W. GIVEN, superintendent of the water department of the city of Monrovia, Cal., for the past 14 years, resigned on July 7, effective Aug. 1.

CHARLES E. DELEUW, assistant chief engineer of the Illinois state highway department, has resigned to devote his entire time to his business in Chicago as a consulting engineer.

CAPT. STANLEY J. HORN has been assigned to duty as military assistant to the United States District engineer at Louisville, Ky. He succeeds CAPT. B. H. TULLEY, transferred to Fort Leavenworth, Kan.

JOHN NORRISON FINLAYSON has been appointed dean of the faculty of applied science and head of the department of civil engineering at the University of British Columbia. Dr. Finlayson is a graduate of Pictou and McGill universities. He has been president of the Professional Engineering Institute of Manitoba since 1919.

ASA H. MORRILL has been appointed chief engineer of the Boston & Maine and the Maine Central railroads. Mr. Morrill has been connected with the Maine Central since 1913. In 1933 he became assistant chief engineer of the Boston & Maine, and last spring was appointed acting chief engineer.

Obituary

C. A. SMITH, WPA area engineer at Somerset, Ky., died on July 20 aged 38.

BURRITT E. TIFFANY, 90, a general contractor in Cleveland for many years, died there on July 19.

HENRY T. MOELLERING, 73, president of the Moellering Construction Co. of Fort Wayne, Ind., died there recently.

EDWARD SHERMAN NETTLETON, city engineer of New Haven, Conn., died on July 23, at the age of 68. Mr. Nettleton had been in the employ of the city for 41 years, the last fifteen in the capacity of city engineer. After his graduation from the Yale Sheffield School in 1892, he was engaged in structural engineering work in New York City.

RICHARD I. C. ASHBRIDGE, formerly assistant city engineer of Philadelphia, and more recently chief engineer of the Atlantic City & Seaboard Ry., died at the age of 75, in Downington, Pa., on July 26.

JOHN A. MCGRATH, 47, a building contractor of Columbus, Ohio, died there on July 21.

THEODORE H. HINCHMAN, architect, engineer, and member of the firm of Smith, Hinchman and Grylls, of Detroit, Mich., died on July 16 at the age of 66. Before the organization of this firm, Mr. Hinchman was connected with the Michigan Central R.R. He was a member of the Michigan State Planning Commission.

JOHN E. BYRNS, a retired building contractor of Cincinnati, Ohio, died there on July 18, at the age of 75.

ORRIN REXFORD died on July 21, age 70. Mr. Rexford was a member of the original survey party in Northern Ontario. Later he was employed on the resurveying of lines of the Canadian Pacific Ry. through the Rocky Mountains.

CONTRACTS AND NEW CAPITAL

CONTRACTS

(Thousands of Dollars)

	Weekly Average July 1935	Prev. 4 Weeks	Week July 30 1936
Federal Government	$3,826	$11,843	$7,588
State and Municipal	12,285	22,255	17,232
Total public	$16,111	$34,098	$24,820
Total private	5,607	13,901	9,780
Week's total	$21,718	$47,999	$34,600
Cumulative to date: 1935	$765,198,000	1936	$1,347,970,000

INDEX NUMBER

ENR Cost	1913 = 100	1926 = 100	ENR Volume	1913 = 100	1926 = 100
July, 1936.	**202.60**	**97.38**	**June, 1936**	**196**	**86**
June, 1936	204.60	98.35	May, 1936	149	65
July, 1935	195.18	93.82	June, 1935	122	54
1935 (Av.)	195.22	93.84	1935 (Av.)	135	58
1934 (Av.)	198.10	95.23	1934 (Av.)	114	50
1933 (Av.)	170.18	81.80	1933 (Av.)	102	47

NEW PRODUCTIVE CAPITAL

(Thousands of Dollars)

1936	Week July 30	Cumulative
State and municipal	$4,439	$310,116
PWA non-federal	....	32,190
RFC loans	....	12,478
Corporate issues	3,020	149,137
PWA loans, Private	....	*—1,665
Total Non-Federal	$7,459	$502,257
Federal	....	691,237
Total new capital	$7,459	$1,193,494
Cumulative to date: 1935	$1,228,015,000	1936	$1,193,494,000

*Bond sales in this classification exceed reallotments during current year.

Note: These figures include private bonds and stocks sold for productive purposes; state and municipal bonds for construction; PWA loans and grants to states and municipalities.

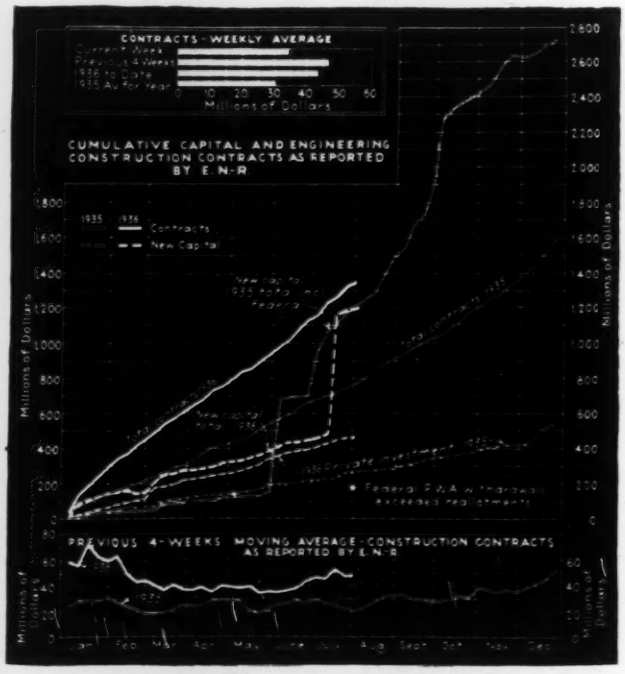
CONSTRUCTION STATISTICS

ENGINEERING construction volume for this week totals $34,600,000 of which private construction is $9,780,000 and public construction, $24,820,000. Of the public, federal is $7,588,000 and state and municipal, $17,232,000. These totals, although below last week and lower than the average week this year, show this year's consistent gain over last year, when the values for the corresponding period were: total, $21,054,000; private, $7,477,000; public, $13,577,000; federal, $3,608,000 and state and municipal, $9,969,000.

Waterworks awards are higher this week but other classifications of new construction fall below the high values reported last week. The classified totals include: commercial buildings, $4,053,000; industrial buildings, $2,517,000; public buildings, $7,437,000; streets and roads, $6,333,000; bridges, $3,672,000; sewerage, $420,000; waterworks, $3,007,000; earthwork drainage, waterways, $2,398,000.

The larger projects awarded this week include: 5-story apartment building, Lockrell Holding Corp., Mt. Vernon, N. Y., $1,000,000; livestock pavilion, State Department of Architecture, San Francisco, Calif., $649,000; superstructures, Blue Grass Park and Aspendale Housing Project, Lexington, Ky., $1,404,000 and Lauderdale Courts Housing Projects, Memphis, Tenn.; $2,183,000; Veterans Hospital, St. Cloud, Minn., $649,000; highways, New York, $974,000; Ohio, $615,000; bridges, Arkansas, $414,000 and bridge in Riley County, State Highway Dept., Kansas, $405,000; removing ledge rock and other material from Harlem River, U. S. Engineers, $782,000; 140-mi. gas line between Pennsylvania gas fields and Dunkirk and Batavia, N. Y., Penn-York Natural Gas Corp., Buffalo, N. Y., $1,500,000.

New capital for the week includes state and municipal bond sales, $4,439,000 and corporate security issues, $3,020,000.


CONTRACTS - WEEKLY AVERAGE
Millions of Dollars
CUMULATIVE CAPITAL AND ENGINEERING CONSTRUCTION CONTRACTS AS REPORTED BY E.N.R.
Contracts
New Capital
Millions of Dollars
PREVIOUS 4-WEEKS MOVING AVERAGE - CONSTRUCTION CONTRACTS AS REPORTED BY E.N.R.